EFFECT OF NOISE ON MACHINERY OPERATORS: A CASE STUDY OF GWADABE MARKET, MINNA, NIGER STATE

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BEING A PROJECT REPORT SUBMITTED TO THE POSTGRADUATE SCHOOL IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF M. ENG. DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING (FARM POWER AND MACHINERY OPTION) FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

OCTOBER, 2010.

DECLARATION

I, **Kaka, Yauri Yusuf** do hereby declare that this research work has been conducted and written by me under the guidance and supervision of Engr. Prof. M.G.Yisa and is never presented elsewhere for the award of any Certificate, Diploma or Degree. Authors whose information was referred to in this work were duly acknowledged.

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15/11/2010
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CERTIFICATION

This Project report titled: Effect of Noise on Machinery Operators: A Case Study of Gwadabe Market Minna, Niger State, by Kaka, Yauri Yusuf (M. ENG./SEET/2004/1124) meets the regulations governing the award of degree of Masters of Engineering in Agricultural and Bioresources Engineering (Farm Power/Machinery option) of the Federal University of Technology, Minna and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

To **Yahaya, Safce, Hassana** and **Hussein**.

ABSTRACT

This research work "Effect of Noise on Machinery Operators" was carried out at Gwadabe Market in Minna, Niger State, Nigeria. A noise survey around the mills was conducted using investigative research approach, a metric tape as well as a standard sound level meter to take measurements. The study revealed that mill operators are exposed to noise level of up to 99.98 dB for more than ten hours daily which is above the internationally accepted maximum allowable limit of 85 dB. Even at a distance of 20 meters away from the mills, noise level still exceeds 85dB, which adversely affected the surrounding traders and could lead to hearing loss with continued exposure. The noise data generated from the study was used to develop a regression model for predicting noise level from a source. A validation test conducted on the model showed 0.2% discrepancy between the predicted sound levels and the measured values. The model could thus be applied to mills at design level to determine the level of insulation required for a system to keep noise levels within acceptable limits.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The nuisance posed by excessive noise in our every day life has become a cause for concern not only to individuals and local organizations but also to Government and International Organizations. Agricultural engineering therefore has focused attention on ergonomics consideration in the design and modification of machines and devices to suit human health, safety and comfort for increased efficiency.

A major occupational hazard for workers in agricultural mills is the noise during the operation of various machines. The owners of these mills do not attached any importance to the exposure of their workers to high-intensity noise or make provision to adopt a suitable control measures. Therefore, one of the major safety concerns has been the exposure of high intensity noise to the workers.

In agricultural practice noise is produced, when operating any agricultural machine and equipment, is it in the process of tillage operation, harvesting, processing and packaging, i.e.-noise at the farmstead. Due to the hazard associated with noise, measuring noise levels and worker's exposure to noise is imperative as part of a workplace hearing conservation and noise control program.

Odigure (1999) classified noise as a problem that affects everybody and is likely to continue as a major issue well into the next century. Noise as a major source of environmental pollution and its long term adverse effect on the auditory system of humans has become a global concern (Odigure *et al.,* 2004). Therefore the need to device ways of reducing the negative health effect of noise is imperative.

1.2 Noise Defined

The word "noise comes from the Latin word nausea meaning "seasickness", referring originally to nuisance noise (www.en.wikipedia. Org/wiki/noise-pollution). Noise is referred to as "any unwanted, meaningless, unmusical sound, unwanted signals produced by a machine. Blake and Mitchell (1978) considered noise to be an unwanted sound as contrasted to interesting conversation, music and pleasing tones. However, sound is the result of physiological stimulation, and to some persons it is noise, while to others it is sound.

Noise can disturb man's work, rest, sleep and communication; it can damage his hearing and evoke other psychological, physiological and possibly pathological reactions (Raju, 2003). However, because of their complexity, their variability and the interaction of noise with other environmental factors, the adverse health effect of noise need to be determined for straight forward analysis.

1.3 Objectives of the study

The objectives of the study are:

1. To conduct a noise survey in old Gwadabe market, Minna in order to determine the level of noise exposure at the market.
2. To determine the health problems associated with excessive noise exposure and the location where the noise is hazardous and where noise is not hazardous.
3. To develop a model for predicting noise level from a source.

1.4 Scope of the study

The survey covered four mill shops arranged in big housing and in each shop there are either two or three milling machines, and during peak hours either two or all the machines are operated at the same time. The noise survey of the Market was carried out with a view to ascertain and recommend ways to reduce the noise exposure of operators and other stakeholders around the market, and hence to improve and reduce the health hazard associated with excessive noise exposure

1.5 Justification of the study

Noise can block, distort, or change the meaning of a message in both human and electronic communications. Worker's exposure to excessive noise over an extended period may lead to many adverse health effects and the introduction of noise source into a given environment can be potentially hazardous, as well as objectionable to residents-depending on the sound level. The need to assess the degree of exposure and possible health effect is paramount so as to educate the operators, owners and the traders about the dangers associated with excessive noise exposure and to find out if the operation and positioning of the machines are in line with ergonomic standard. This is imperative in order to conform to ergonomic practices of enhancing workers health and safety during operation.

The concentration of mills, at the old Gwadabe Market at the time of this study makes the area noisy, and the noise is so high that it poses a health threat not only to the mill operators but also to the surrounding traders. This fact necessitated this study to determine the level of exposure and the position where exposure is likely to be hazardous.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Review of Selected Literature

In common use, the word noise means unwanted sound or noise pollution. When speaking of noise in relation to sound, what is commonly meant is meaningless or loud sound and may be referred to as noise. Noise propagation is displeasing human or machine created sound that disrupts the activity or happiness of man.. Shiru (2002) defined noise as any unwanted sound generated by the vibration of surface or by turbulence in an air stream which set up rapid vibration in the surrounding air.

Blake and Mitchell (1978), considered noise to be an unwanted sound as contrasted to interesting conversation, music and pleasing tones. Environmental noise is displeasing to human and disrupts the activity or happiness of human or animal life. Communication in high noise situations and environments like a crowded market or restaurant can be challenging for normal hearing individuals and close to impossible for people with high frequency sensory losses (Delconte, 2004). People with difficulty in hearing have to overcome the disabling effects of the sensory loss, couple with the powerful background noise, as background noise comprised largely of low frequency energy.

Noise is one of the common occupational hazards and therefore there is evidence to support the increasing prevalence of high noise levels in the workplace (Malamed, *et.al.,* 2001).

The collection of health consequences of elevated sound levels, constitute one of the most widespread public health threats in industrialized and developing countries. Current condition exposes tens of millions of people to sound level capable of provoking hearing loss, apart from other induced health impacts like hypertension, vasoconstriction and cardiovascular problems (USSPWC, 1972). Apart from the potential of producing hearing loss, noise exposure has been reported to illicit a number of non – auditory or extra – auditory responses and can have some predictable effects on performance (Dobbs, 1972).

The major source of agricultural machinery noise is normally from different parts and depends on the type of machine i.e whether it is a vehicle, appliances, or in industries. However, components such as bearings, gear, fans and some other mechanisms generate most of the noise in machinery.

Studies by Raju (2003) and Kryter (1971), reported a variety of physiological changes that can occur in the human body which can be related to noise. Physiological changes that can occur in response to noise include the release of adrenaline into the blood stream, increase in blood pressure, heart rate and respiration, inhibited gastrointestinal motility, peripheral blood vessel constriction and tension of muscles (Passchier-Vermer, 1993). Theoretical and empirical considerations suggest that, the physiological effect of noise exposure might at least in part be mediated by psychological factors (Sarafino, 1994). However, Sieber *et.al.*,(1992) and Brennan *et.al.*,(1992) reported that psychological effect of noise which normally lead to psychological stress is known to have negative impacts on immunity and cholesterol. Rosengren *et.al.*,(1991) reported in their studies that, self-reported psychological stress due to noise exposure may be associated with cardiovascular and cerebrovascular morbidity and mortality. The effect of noise can manifest themselves, in a number of ways, which include general illness, neurophysiologic disturbances such as headaches, fatigue, insomnia, irritability, neuroticism, cardiovascular disturbances, such as hypertension and cordial disease and finally digestive disorders such as ulcers, colitis and various endocrine and other biological disorders, (Kryter,1971).

The mechanism of hearing loss arises from trauma to stereo celia of the cochlea, the principal fluid filled structure of the inner ear. The Celia damage is known to be cumulative and irreversible (Schneider *et al.*, 2002). Recent research indicates that high noise levels create elevated levels of reactive oxygen species in the inner, ear, which interferes with the regenerative process for celia repair. The research shows why high noise levels have differing effect over a given population, and lead to a possible preventative strategy for adequate antioxidant intake.

The human ear is an extremely delicate and sensitive instrument that day in and day out we have a tendency to take for granted. This dynamic sense organ allows us to learn the spoken language when we are young, hear speech and understand the communication of others, be alerted to warning signals and to enjoy the peaceful sound of nature.

In a single day, the human ear can be attuned to the softest sounds like rustling of leaves (20 dB) and challenged by the over bearing and potentially harmful intensities of powerful machines/engines.

Keeping our hearing healthy and in "normal" range is becoming a greater and a greater challenge in the world we live. From an audiometric standpoint, normal hearing thresholds range from zero dBHL (decibel hearing level) to 25 dBHL, i.e from 125Hz to 8000 Hz (CCOHS, 2005). A hearing threshold can be defined as the intensity level in dBHL that an individual detects a single pure tone 50% of the time. Though hearing loss can be accounted for by a number of congenital and medical etiologies, and is largely as a result of the aging process (Presbycusis). Noise is regarded by a number of authorities as one of the leading causes of hearing impairment in the general population.

Miller (1974) stated that early effects of noise exposure on the hearing sense organ lead to decreased hearing sensitivity at 2000 Hz to 8000 Hz range. With repeated unprotected exposure to loud noise, hearing loss can progress. With precipitous high frequency sensor neural hearing losses, hearing thresholds generally become worse as the frequencies increase, so the process can be progressive and permanent.

Kryter (1971), reported some physiological response or symptoms related to noise exposure and these include, responses of anger, anxiety, irritability, emotional stress, reduction in morale and motivation, distraction, poor judgment, mental fatigue, and disturbance of sleep. Job and task performance can also be greatly affected by the presence of loud noise (Miller, 1974). Many studies suggested that noise is more likely to reduce overall accuracy rather than the total quantity of work, and is more likely to affect the completion of complex tasks than the completion of simple tasks (Delconte, 2004).

Kahneman (1973) observed that depending on the complexity of the task, noise may either improve or interfere with performance. Tasks that are mechanical or repetitive will clearly be affected when the expectations for performance are average. Monotonous tasks performed in the presence of moderate levels of noise can illicit beneficial arousal levels and therefore may favourably affect performance. Examining the effect of noise on efficiency in the work place is difficult, since noise is usually accompanied by additional stressors such as heat and vibration. But generally the synergetic effects of these stressors do alter an individual arousal state and can directly affect performance.

Human ears are exposed to variety of loud noise during the lifetime. It is the cumulative effects of this loud noise on the auditory system that can result in hearing loss. Noise induced hearing loss typically occurs from unprotected, repeated and prolonged exposure to loud noise. These loud noise can be constant or intermittent; high frequency or low frequency or combinations thereof. A single loud impact noise like an explosion can result in immediate shifts in hearing sensitivity. This type of acoustic trauma can be severe and often permanent (Berger and Casali, 1998).

Noise propagation is normally through compressible media such as air or water (though noise can propagate through solid as well).

Noise is a sequence of wave pressure, which propagates through compressible media such as air or water though noise can propagate through solids as well). During noise propagation, waves can be reflected, refracted or attenuated by the medium.

2.2 Noise Produced by Machines

To determine the acceptability of the noise produced by a noise source, the noise emission must be determined. The noise emitted by an aircraft or any moving source e.g. vehicle is usually described by the sound pressure level at certain defined location. However, stationary sources particularly those, which operate in a well-defined environment or are small enough to be moved into one, are usually described by their sound power output (Anderson and Bratos – Anderson, 1993).

If the sound pressure level or the sound power level of a source has been determined and found to exceed certain criteria, then it may be necessary to reduce the noise emission of the source by engineering methods.

Noise generation in machinery is mainly of two main sources. These are (1) air borne sound sources caused by gas fluctuations (as in the fluctuating release of gas from an engine exhaust and (2) structure borne machinery vibration sources that in turn create sound fields (for example engine surface vibration). Moreover, those sound pressure and vibration sources are of two types; (i) steady state and (ii) impulsive. Both steady state and impulsive vibrations (caused by impacting parts) are commonly encountered in machines. The path may be air- borne or structure borne in nature, and the process responsible for vibrations according to Odukoya (2006) are:

a. Friction
b. Fluctuating Load
c. Hydraulic Noise
d. Electrical Noise
e. Resonance

However, Crocker (1998), reported that the major sources of machinery noise is normally from different parts and depends on the type of machine i.e. whether it is a transportation vehicle, an appliance or in industries. However, components such as bearing, gears, fans and some other mechanisms generate most of the noise in machinery.

2.3 Noise Measurement

Noise is produced by the vibration of bodies or air molecules and is transmitted as a longitudinal wave motion. Noise is a form of mechanical energy and is measured in energy related units.

The sound output of a sources is measured in watts and the intensity of sound at a point in space is defined by the rate of energy flow per unit area, measured in watts per ms intensity is proportional to the mean square of the sound pressure and as the range of this variable is so wide, it is usual to express its value in decibel (dB).

The simplest method involves the measurement of the sound pressure level (SPL) through a filter or network of filters that represent the frequency response of the ear, and such frequency weighted measurements is referred to simply as noise levels. Measurement of sound level may be averaged over two distinctly different periods of time. Steady sound levels and instantaneous levels of variable sounds are measured on a very short time scale of 1 second or less. Variable sounds can be measured with a much longer average time, over periods of hours if necessary, and are expressed in terms of the equivalent continuous sound pressure level. Anderson and Bratis-Anderson (1993) stated that there are many methods and indices used for predicting human reaction to various noise levels; the sound level meter is used to measure the noise levels.

2.4 Effect of Noise

The ear functions without a risk of permanent damage when sound levels operated is below 85 dB (Blake and Mitchell, 1978). Studies by Jansen (1992) shows that in industrialized nations, an estimated 15 – 20% or more of the working population, are exposed to sound levels between 75 – 86 dB. Lyon (1987) added that this noise is from different kinds of machinery and the noise increases with the power of the machine.

However, Yisa (2005), Smith *et.al.*,(1994), and Washington(2004), opined that exposure to noise levels greater than 85 dB for eight hours daily seriously damages health, i.e. exposure duration of 40hours per week of equivalent noise level of 85 dB. Many studies have shown that exposure to noise levels for a longer period can lead to many health consequences. Studies by United States Environmental Protection Agency (EPA) specify a maximum outdoor level of 60 to 65 dB, while occupational safety organizations (NIOSH,1996), recommended that the maximum exposure to noise is 40 hours per week at 85dB. For every additional 3dB, the maximum exposure time is reduced by a factor of 2, e.g.20 hours per week at 88 dB. The ear functions without a risk of permanent damage when the sound levels it operated is below 85dB. Physical feelings occur when the levels exceed 85dB to 120dB. Any sound level above 140 dB result to pains and hearing impairment occurs depending on exposure time, (Blake and Mitchel, 1978). Scholars like Fields (1994), Job and Hartfield (1998), Hartfield (2001),shows there is ample evidence for the claim that excessive noise exposure promote negative psychological reactions and psychological stress (Evans *et.tal.,2005*). Indeed, numerous researchers Lercher and Widman, (1993), Lercher, (1996),Van Kamp, (1990) have demonstrated a positive association of psychological reaction to noise exposure with self-reported symptoms.

2.4.1 Hearing Impairment

Normal hearing is regarded as the ability to detect sounds in the audio frequency range (16 – 20000 Hz) according to established standards. Roberts and Bayliss (1967) stated that, individual hearing ability in man varies, and the variation may be due to the different effect of environmental influences.

In discussing the effect of noise on hearing, it is imperative to differentiate between hearing level, noises induced threshold shift (NITS) and hearing impairment.

Hearing level refers to the audiometric threshold level of an individual or group in relation to an accepted audiometric standard (ISO-1999) and is sometimes referred to as hearing loss".

Noise induced threshold shift is the quality of hearing loss attributable to noise alone, after values for presbycusis have been subtracted (Gallo and Gloring, 1964).

However, international standard organization (ISO-1999) has set out comprehensive information on the risk of loss of hearing in relation to age.

Hearing impairment is generally referred to as the hearing level at which individual begin to experience difficulty in leading a normal life, usually in relation to understanding speech.

2.4.2 Hearing Loss

The long –term effect of noise is hearing loss. Hearing loss due to industrial noise has been studied by many researchers (Celik *et.al., 1998, Miyakita et.al., 2004*). However, hearing loss does not occur in sudden and traumatic manner, but it is imperceptibly slow and painless .At first, the workers are unaware of it, and gradually they notice loss of hearing (Grandjean, 1988). This can either be temporary or permanent depending on the degree of exposure and the period of exposure.

Noise induced temporary threshold shift is a temporary loss of hearing acuity experienced after a relatively short exposure to excessive noise. From experience, a person entering a noisy area may experience a loss in hearing sensitivity, but can recover after returning to a quiet area. This can be measured as a shift in audiometric threshold and is referred to as Noise Induced Temporary Threshold Shift (NITTS).

Recovery from this depends on the severity of the hearing shift, individual susceptibility and the degree of exposure. When it becomes difficult to recover from this shift before the next exposure, there is possibility that some of the loss may become permanent.

In noise induced permanent threshold shift (NIPTS), the loss is sensor neural, it is seen in both ear and bone conduction audiograms. Noise-induced hearing loss is not an abrupt process but occurs gradually, usually over a period of years. The rate and extent of loss depends on the severity and the duration of the exposure, but individual susceptibility also seems to have considerable effect on the progression.

Noise-induced losses are similar to losses due to aging and the two types of losses are difficult, if not impossible to distinguish. However, some scholars opined that there is no experimental evidence that shows this is so. But Schneider *et. Al*., (2002) indicated that there is probably no causal relationship between age and susceptibility to noise induced permanent threshold shift (NIPTS), at least in people of working age.

2.4.3 Occupational Hearing Loss

Several studies have been published on the subject of occupational hearing loss. Virtually every study revealed that workers exposed to intense noise daily for several years, showed noise induced hearing loss at higher frequency, but hearing loss was rare at lower frequency. A clear relationship was generally seen between increasing incidence of hearing loss and increasing noise level. Kawata and Suga (1967), reported sudden deafness occurring after long term exposure to noise without previous impairment and hence indicate special susceptibility.

Another study conducted in Germany have revealed that the mills used for handling cereal crops had a noise level more than 95dB (Anonymous, 2003). Cohen *et al.* (1970) in their studies compared the mean hearing levels of exposed workers with those of a control group for several noise intensities and several durations of exposure and found that noise levels between 85 and 88dB could be harmful to ear, and that even at 75 dB there was some loss of hearing. Studies also by Jansen (1992) revealed definite risk of hearing damage associated with prolonged exposure to noise levels between 85 and 90 dB.

2.4.4 Interference with Communication

It is generally believed that interference with speech in occupational situations may lead to accidents due to inability to hear warning shouts. In schools, offices and homes, speech interference is a major source of annoyance. Many attempts have been made to develop a single index of such interference, based on the characteristics of the masking noise, that directly indicates the degree of interference with speech perception (CCOHS, 2005).

2.4.5 Disturbance of Sleep

Noise intrusion can cause difficulty in falling asleep and can awaken people who are asleep. Noise can also distort communication and lead to accidents in industries (Raju, 2003). Studies by United Nations Environmental program (UNEP), indicated that disturbance of sleep becomes increasingly apparent as ambient noise levels exceed 35 dB and that the probability of subjects being awakened by sound level of 40 dB is 5% and increases to 30% at 70 dB. It has also been observed that subjects who sleep well at 35 dB complained about sleep disturbance and have difficulty in falling asleep at 50 dB.

2.4.6 Annoyance

Noise annoyance may be defined as a feeling of displeasure evoked by a noise. The annoyance inducing capacity of noise depends upon many of its physical characteristics including its intensity, spectral characteristics, and variations of these with time (Broadbent, 1971). However, annoyance reactions are sensitive to many non – acoustics factors of social, psychological, or economic nature and there are considerable differences in individual reactions to the same noise.

The criteria linking noise exposure and annoyance led to the development of many methods for the measurement of both variables. In most surveys, questionnaires are used to access the annoyance felt by an individual in response to various types of noise. Whatever noise scale is used to express noise exposure, it must be recognized that, at any level of noise annoyance, reactions will vary greatly because of psychosocial differences. A study by Barreiro *et al.*, (2005) conducted in Spanish cities revealed that in urban areas households are willing to pay approximately four euros per decibel per year for noise reduction.

2.4.7 Effect on Performance

The effect of noise on the performance of tasks in work situations and as it affects human productivity have been studied. It is evident that when a task involves auditory signals of any kind, noise at intensity sufficient to mask or interfere with the perception of these signals, will interfere with the performance of the task. Miller (1974) reported that job and task performance in work situations can be greatly affected by loud noise.

Noise can act as a distracting stimulus, depending on how meaningful the stimulus might be, and may also affect the psycho physiological state of the individual. Noise can change the state of alertness of an individual and may increase or decrease efficiency. Kahneman (1973) stated that depending on the complexity of task, noise may either improve or interfere with performance. Performance of tasks involving motor or monotonous activities is not always degraded by noise, but mental activities involving analytical processes, vigilance, information gathering appear to be particularly sensitive to noise. Broadbent (1971) in his studies affirmed that overall work rate may not be affected, but with high noise the incidence of accidents that can occur in the work place are reportedly higher.

2.5 Noise Control

Noise control should always be attempted at the design stage wherever possible because there are more low cost options and possibilities rather than to make individual machines or installation quieter (Lyon, 1987). After machines are built or installation completed noise control approaches can still be achieved through various modifications and add – on treatments, but these are frequently more difficult and expensive.

2.6 How Noise propagate from the mills

All media have three properties which affect the behaviour of sound propagation viz:-

a) A relationship between density and pressure. This relationship, affected by temperature, determines the speed of sound within the medium.

b). The motion of the medium itself, e.g., wind. Independent of the motion of sound through the medium; if the medium is moving, the sound is further transported.

c) The viscosity of the medium, which determines the rate at which sound, is attenuated.

Noise problem can take the form of source – path – receiver model as shown in Figure 2.1.

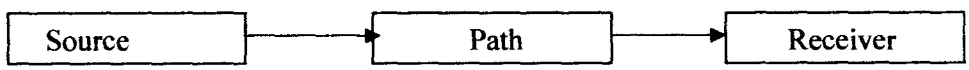


Fig. 2.1: Source – Path – Receiver Model

Source: Crocker and Kessler (1982).

Source modifications are the best practice but are sometimes difficult to accomplish, often changes in the path or at the receiver may be the only real options available. In reality there will be many sources and paths. The dominant source should be treated first, then the secondary one and so on. The same procedure can be applied to the paths. Finally, when all other possibilities are exhausted, the receiver can be treated (Crocker, 1998). If as in most noise problems, the receiver is the human ear, earplugs or earmuffs or even complete personnel enclosures can be used.

The dominant source (paths) can sometimes be determined from careful experiments. In some cases, parts of a machine can be turned off or disconnected to help identify sources. In some cases, parts of a machine can be enclosed, and then sequential exposure of machine parts can be used to identify major sources.

2.7 Noise Generation in Machinery

In noise generation to determine the acceptability of the noise produced by a noise source, the noise emission must be determined. The noise emitted by aircraft or any moving source e.g. vehicle is usually described by the sound pressure level at a certain defined location. However, stationery sources particularly those which operate in a well – defined environment or are small enough to be move into one are usually described by their sound power output (Anderson and Bratos – Anderson, 1993). But if the sound pressure level or the sound power level of a source has been determined and found to exceed certain criteria, then it may be decided to reduce the noise emission of the source by engineering methods.

Noise generation in machinery is mainly from two main sources. These are (1) airborne sound sources caused by gas fluctuation (as in the fluctuating release of gas from an engine exhaust and (2) structure borne machinery vibration sources that in time create sound fields (for example, engine surface vibration).

Moreover, these sound pressure and vibration sources are of two types: (1). Steady state and (2) Impulsive. Both steady–state and impulsive vibration (caused by impacting parts) are commonly encountered in machines. The path may be air-borne or structure borne in nature.

The major sources of machinery noise is normally from different parts and depends on where the type of machine is i.e. weather it is a transportation vehicle, in appliances or in industries. However, components, such as bearings, gears, fans and some other mechanism generate most of the noise in machinery (Crocker, 1998).

2.8 Hearing Protection Devices

A hearing protection device (HPD) is a personal safety product that is worn to reduce the harmful auditory and/or annoying subjective effects of sound.
Hearing protectors are often a method of last result, when other means such as engineering controls or removals of the person from the noisy environment is not practical or economical.

The research and development in hearing protection began during World War II in response to the tremendous hearing loss caused by military weapons (Berger and Casali, 1998). Military and industrial hearing conservation programs and the use of hearing protection followed in the early 1950s with use proliferating in early 1970s. However, by 1980 many countries came up with regulations mandating use of hearing protection in occupational settings (Berger and Casali, 1998).

2.8.1 Types of Hearing Protection Devices (HPD)

Different devices are available for protecting the ear against loud sound. These devices may be broadly categorized into earplugs, which are placed into or at the entrance of the ear canal to form a seal and block sound. Earmuffs, which fit over and around the ears (circum aural) to provide an acoustics seal against the head, and helmets, which normally encase the entire head. Although in certain cases acoustical concerns may dictate the selection of a particular type of HPD, normally ergonomics considerations, personal preference, and/or compatibility with other safety gear and job requirements are the deciding factors.

2.9 Noise Reduction Techniques

Many successful well documented methods are used to reduce the noise of machineries. Crocker (1998) classified these methods using the source – path – receiver model.

Crocker (1998) added that some of the most useful approaches can generally be used only at the source or in the path and others, such as enclosure, can be adapted for use at any location. For instance, enclosure can be built inside a machine around the gear or bearing, or a larger enclosure or room can be built around a complete machine. Also, enclosure or personnel booth can be built for the use of a machine operator. Table 2.1 summarizes a large number of approaches that have been found useful in practice.

Table 2.1: Various Noise Control Approaches that may be Considered for Source, Path, or Receiver

Source	- Choose quietest machine source available - Reduce force amplitudes - Apply forces more slowly - Use softer materials for impacting forces - Balance moving parts - Use better lubrication - Improve bearing alignments - Use dynamic absorbers - Change natural frequencies of machine elements - Increase damping of machine elements - Isolate machine panels from forces - Put holes in radiating surfaces
Path	- Install vibration isolators - Use barriers - Install enclosures - Use absorbing materials - Install reactive or dissipate mufflers - Use vibration breaks in ductwork - Use line duct and plenum chambers - Use flexible ductwork - Use damping materials
Receiver	- Provide earplugs or earmuffs for personnel - Construct personnel enclosures - Rotate personnel to reduce exposure time - Locate personnel remotely from sources

Source: Crocker and Kessler (1982).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials and Methods Adopted

The study area is old Gwadabe market situated in Minna, the capital of Niger State. The market is situated south-east of the Minna central market and is a busy area for fruits sellers, second hand clothes, freash tomatos, and foodstuff. Niger State is one of the 36 States that made up the Federal Republic of Nigeria. Niger State was created on the 3rd of February, 1976 and carved out of the former North – Western State, and now is the largest state in Nigeria and covers a total land area of 76,363 square kilometers or about 9% of Nigeria's total land area and lies between latitude $8^0 20'$N and $11^0 30'$N and longitude 3^0 30'E and 7^0 20' E. The state is bordered by Zamfara State to the north and Kebbi State to the northwest, to the south by Kogi State, Kwara State to the southwest while Kaduna State and Federal Capital Territory bordered the state to the northeast and southeast respectively (figure 3.1). Based on 2006 population census, the state has a population of 4,082,558 million (State).

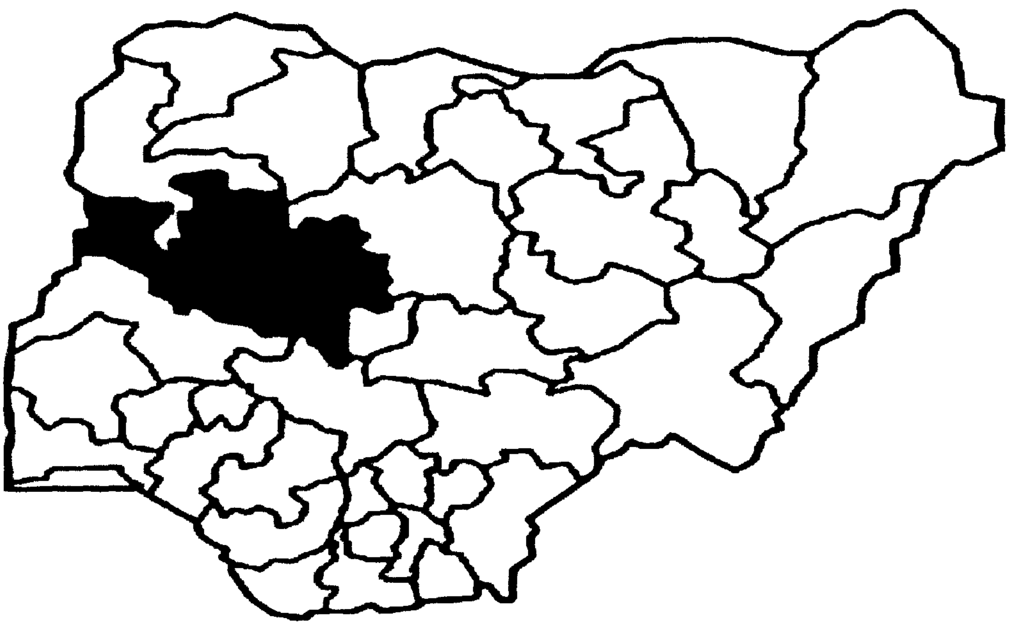


Fig 3.1 Map of Nigeria showing the location of Minna, in Niger State

The Gwadabe market is always crowded with villagers who normally bring fruits and foodstuff to the city dealers and the second clothes dealers who bring in their materials from the western part of the country on the other side and the residents of the city who are there to purchase from the dealers and directly opposite them there is a big wood (plank) and zinc building partitioned into four which serve as the mill building. The building is partitioned into four unequal parts each having two to three grinding machines in it. In conducting noise measurement in this study, a sound level meter model CEL 593 was used. Because the effects of noise depend strongly upon frequency of sound pressure oscillation, therefore spectrum analysis is important in noise measurement. The study involves carrying out a noise survey, and these involve measuring noise level at selected locations throughout the entire section to identify noisy areas. The measurement was carried out using a sound level meter (SLM).

The following instruments were used in carrying out the research:

1. Sound level meter – used for measuring noise level

   Model – CEL 593

   Company – Cell instruments limited England.

2. Camera – used to take photographs

   Model – Kodak easy share Digital Camera V803

   Company – Eastman Kodak Company, Rochester NY 14650

3. Measuring tape – A 50m length tape was used for taking measurement in the area where reading of the noise levels were recorded and it is also used to measure the various dimensions in and around the mills.

A questionnaire (Appendix A) was designed to find out the extent to which noise affects operators and possible health implication. The questionnaire administered could not be completed by the operators and owners of the mills, because they are illiterates. Oral interviews were therefore conducted by asking the same questions on the questionnaire. The research carried out is represented by figures and tables showing all the points or locations where noise levels were recorded. The points for the minimum and maximum noise levels in the study area are also established.

The measurements were carried out at different locations. The co-operation of the mill owners were solicited to put one machine on in shop A while shutting off the remaining machines in the other shops, and the process was repeated in each shop. Noise levels were recorded in each shop at operator's ear level, then at an interval of 5 meters, 10 meters, 15 meters, 20 meters and 25 meters, in different direction of each shop (i.e. from N, S, E, W).

Then, the mill owners were requested to put two machines in operation in each shop one after the other, and the noise levels were recorded at operators ear level and in all the four directions at 5m, 10m, 15m, 20m and 25metres.

After this, two machines were switched on in all the shops, and noise levels were also recorded at each operator's ear level, and then at the intervals of 5, 10, 15, 20 and 25 meters respectively.

The same procedure stated above was adopted to conduct another noise survey at the New Kure Central market but here the intervals considered are at operators ear level, then at an interval of 7, 14, 21, 28 and 35 metres.

. The operators and owners were interviewed to ascertain if there's any adverse health effects experienced due to the exposure. The design, location and the way the operation (milling) is carried out was also looked into to determine if the position, operation, safety and comfort of the operators were considered in the design for the operators to enhance their productivity.

3.2 Method of Model Development

To develop the model, the data generated from the result of the noise survey conducted in and around the mill building were used. Noise levels recorded from six(6) distances of ear level (0.5m), 5m, 10m, 15m, 20m, and 25m away from each of the noise source (machines) and taken from the four corner points of north, south, east and west direction from the mills were used. A multiple regression model given by $Y=B_O+B_1X_1+B_2X_2+e$ as expressed by Montgomery (1991) is used to build a quantitative model relating the two factors considered in the study (i.e. X_1= distance and X_2= number of machines) on the response Y (i.e .noise level). The regression coefficients were however evaluated using Crammers rule as expressed by Ilori and Ajayi (2000).

CHAPTER FOUR

4.0 RESULTS

4.1 Presentation of Result

The following tables and figures displays the result of the research conducted. Table 4.1 is the dimensions of the entire mill housing. Tables 4.2 to 4.5 shows the noise level of mills A – D when only one machine was operating separately in each shop. Tables 4.6 – 4.9 shows the noise level of mills A – D when two machines are operating in the particular shop shown while machines in the other shops were off. Table 4.10 is the noise level of mills A – D when all the machines (8) are operating. Table 4.11 is the average noise levels of all the readings in all direction. Tables 4.12, 4.13 and 4.14 shows the data used to develop the model, validation test result and data used to determine the accuracy of the model respectively. Tables 4.15 to 4.18 are the noise levels of the new Kure market for mills A – D with only one machine operating separately in each shop .Tables 4.19 to 4.22 are the noise level for mills A – D when two machines are operating independently in each shop. Tables 4.23 and 4.24 are the noise levels for mills A – D with all the machines (8) operating and the average noise levels of all the mills respectively. Table 4.25 is the data used to determine the accuracy of the new readings in kure market.

Table 4.1: Mill Shops and their Dimensions

S/No	Mill No.	Length (m)	Width (m)	Height(m)
1	Mill A	4.60	5.00	3.15
2.	Mill B	4.78	5.00	3.15
3.	Mill C	5.50	5.00	3.15
4.	Mill D	4.71	5.00	3.15

Table 4.2: Noise Level for Mill A MC1

PT	N(dB)	S(dB)	W(dB)
Ear Level	92.9		
5m	91.0	91.1	91.4
10m	88.5	84.2	90.0
15m	86.9	83.9	88.6
20m	77.5	78.6	85.1
25m	72.0	76.7	79.3

Note: MC = machine

Table 4.3: Noise Level for Mill B MC1

PT	N(dB)	S(dB)
Ear Level	92.8	
5m	91.5	91.7
10m	89.5	89.3
15m	86.4	88.0
20m	84.6	85.2
25m	80.6	80.3

Table 4.4 NoiseLlevel for Mill C MC1

PT	N(dB)	S (dB)
Ear Level	92.7	
5m	88.7	90.5
10m	82.6	88.4
15m	80.6	84.7
20m	77.3	81.9
25m	74.6	80.3

Table 4.5 NoiseLevel for Mill D MC1

PT	N(dB)	S(dB)	E(dB)
Ear Level	93.1		
5m	90.6	91.2	89.6
10m	86.6	87.1	88.0
15m	84.0	85.8	82.6
20m	82.4	80.0	80.9
25m	81.0	77.6	71.5

Table 4.6: Noise Level for Mill A Machine 1 and 2 Operating

PT	N (dB)	S(dB)	W(dB)
Ear Level	95.9		
5m	94.1	93.4	91.7
10m	89.7	92.0	89.0
15m	87.0	89.1	87.3
20m	85.3	87.2	84.1
25m	82.1	78.7	80.5

Table 4.7 Noise Level for Mill B, Machine 1 and 2 Operating

PT	N (dB)	S(dB)
Ear Level	95.1	
5m	92.0	94..2
10m	89.9	90.1
15m	88.7	89.8
20m	87.0	86.2
25m	76.3	85.0

Table 4.8: Noise Level for Mill C, Machine 1 and 2 Operating.

PT	N (dB)	S(dB)
Ear Level	95.5	
5m	93.7	92.2
10m	90.6	90.0
15m	88.9	88.2
20m	84.0	82.7
25m	82.6	81.1

Table 4.9: Noise Level for Mill D, Machine 1 and 2 Operating.

PT	N(dB)	S(dB)	E(dB)
Ear Level	94.3		
5m	90.9	92.0	91.8
10m	89.3	90.0	91.3
15m	87.6	88.4	89.9
20m	87.0	86.3	89.1
25m	84.1	85.0	79.0

Table 4.10: Noise Level for Mills ABCD with Two Machines Each Operating

PT	N(dB)	S(dB)	E(dB)	W(dB)
Ear Level	98.9	99.2	97.4	99.9
5m	97.7	95.6	97.0	97.0
10m	96.6	93.2	90.8	91.7
15m	89.3	90.8	87.0	90.5
20m	85.6	88.1	85.5	85.9
25m	83.0	84.0	81.7	82.8

Table 4.11: Average Noise Levels of all the Readings in all Directions in Mills A-D

Point	A	B	C	D	Average Value
Ear L.	92.9	92.8	92.7	93.1	92.9
5m	91.2	92.3	89.6	90.5	91.0
10m	87.6	89.4	85.5	87.2	87.4
15m	86.5	87.2	82.7	86.9	85.8
20m	80.4	84.9	79.6	81.1	81.5
25m	76.0	81.5	77.5	76.7	78.0
Ear L.	95.9	94.3	95.5	95.7	95.4
5m	93.1	93.1	93.0	91.3	92.6
10m	90.2	89.8	90.3	90.2	90.1
15m	87.8	87.8	88.6	88.6	88.2
20m	85.5	86.1	83.4	87.5	85.6
25m	79.6	78.7	81.9	82.7	80.7
Ear L.	98.9	99.2	97.4	99.9	98.9
5m	97.7	95.6	97.0	98.2	97.1
10m	96.6	93.2	90.8	91.7	93.1
15m	89.3	90.8	87.0	90.5	89.4
20m	85.6	88.1	85.5	85.9	86.3
25m	83.0	84.0	81.9	82.8	83.0

Table 4.12: Data used for the Model

EXP	Y	Y^2	X_1	X_1^2	X_2	X_2^2	X_1Y	X_2Y	X_1X_2
1	92.9	68630.41	0.5	0.25	1	1	46.45	92.9	0.5
2	91.0	8281.00	5	25	1	1	455	91.0	5
3	87.4	7638.76	10	100	1	1	874	87.4	10
4	85.8	7361.64	15	225	1	1	1287	85.8	15
5	81.5	6642.25	20	400	1	1	1630	81.5	20
6	78.0	6084.00	25	625	1	1	1950	78.0	25
7	95.4	9101.16	0.5	0.25	2	4	47.7	190.8	1
8	92.6	8574.76	5	25	2	4	463	185.2	10
9	90.1	8118.01	10	100	2	4	901	180.2	20
10	88.2	7779.24	15	225	2	4	1323	176.4	30
11	85.6	7327.36	20	400	2	4	1712	171.2	40
12	80.7	6512.49	25	625	2	4	2017.5	161.4	50
13	98.9	9781.21	0.5	0.25	8	64	49.45	791.2	4
14	97.1	9428.41	5	25	8	64	485.5	776.8	40
15	93.1	8667.61	10	100	8	64	931	744.8	80
16	89.4	7992.36	15	225	8	64	1341	715.2	120
17	86.3	7447.69	20	400	8	64	1726	690.4	160
18	83.0	6886.00	25	625	8	64	2075	664	200
$\sum$	**1597**	**142257.36**	**226.5**	**4125.75**	**66**	**414**	**19314.6**	**5964.2**	**830.5**

$\sum y = an + b_1 \sum x_1 + b_2 \sum x_2$

$1597 = an + 226.5b_1 + 66b_2$ (1)

Using

$\sum x_{1Y} = a\sum x_1 + b_1 x_1^2 + b_2 \sum x_1 x_2$

$= 19314.6 = 226.5_a + 4125.75b_1 + 830.5b_2$ (2)

Also using

$\sum X_2 y = a \sum X_2 + b_1 \sum X_1 X_2 + b_2 \sum X^2_2$

$5964.2 - 66a + 830.5b_1 ++ 414b_2$ (3)

Solving the above three equation using crammer's rule

$$D = \begin{pmatrix} 18 & 226.5 & 66 \\ 226.5 & 4125.75 & 830.5 \\ 66 & 830.5 & 414 \end{pmatrix} = \begin{pmatrix} 1597 \\ 19314.6 \\ 5964.2 \end{pmatrix}$$

Find the determinants of the matrix

$|D| = 18 ((4125.75 \text{ x} 414) - (830.5 \text{x} 830.5)) - 226.5 ((226.5 \text{ x } 414) - (830.5 \text{x} 66) + 66$

$(226.5 \text{ x } 830.5) - (4125.75 \text{ x } 66)$

$= 18 (1708060.5 - 689730.25) - 226.5 (93771 - 54813) + 66 (188108.25 - 272299.5)$

$= 18 (1018330.5) - 226.5 (38958) + 66 (-84191.25)$

$= 18329945 - 8823987 - 5556622.5$

$|D| = 3949336$

$$|D_1| = \begin{pmatrix} 1597 & 226.5 & 66 \\ 19314.6 & 4125.75 & 528.5 \\ 5964.2 & 830.5 & 414 \end{pmatrix}$$

$= 1597 (4125.75 \times 414) - (830.5 \times 830.5) - 226.5 (19314.6 \times 414) - (5964.2 \times 830.5)$

$+ \ 66 (19314.6 \times 830.5) -(5964.2 \times 4125.75)$

$= 1597 ((1708060.5 - 689730.25) - 226.5 (7996244.4 - 4953268.1) + 66$

$(16040775.3 - 24606798.15)$

$= 1597 (1018330.25) - 226.5 (3042976.3) + 66 (-8566022.85)$

$= 1626273409 - 689234132 - 565357508.1$

$|D_1| = 371681769.2$

$$|D_2| = \begin{pmatrix} 18 & 1597 & 66 \\ 226.5 & 19314.6 & 830.5 \\ 66 & 5964.2 & 414 \end{pmatrix}$$

$D_2 = 18 ((19314.6 \times 414) - (830.5 \times 5964) - 1597 ((226.5 \times 414) - (830.5 \times 66) + 66$

$((226.5 \times 5964.2) - (19314.6 \times 66)$

$= 18 (7996244.4 - 4953268.1) - 1597 (93771 - 54813) + 66 (1350891.3 - 1274763.6)$

$= 18 (3042976.3) - 1597 (38958) + 66 (76127.7)$

$= 54773573.4 - 62215926 + 5024428.2$

$|D_2| = - 2417924.4$

$$|D_3| = \begin{pmatrix} 18 & 226.5 & 1597 \\ 226.5 & 4125.75 & 19314.6 \\ 66 & 830.5 & 5964.2 \end{pmatrix}$$

$|D_3| = 18 (4125.75 \times 5964.2) - (19314.6 \times 830.5) - 226.5 (226.5 \times 5964.2)$

$- (19314.6 \times 66) + 1597 ((226.5 \times 830.5) - (4125.75 \times 66)$

$= 18\ (24606798.15 - 16040775.3) - 226.5\ (1350891.3 - 1274763.6) + 1597$

$(188108.25 - 272299.5)$

$= 18\ (8566022.85) - 226.5\ (76127.7) + 1597\ (-84191.25)$

$= 154188411.3 - 17242924.05 - 134453426.3)$

$|D_3| = 2492060.95$

Now we find a, b_1 and b_2 by

$$a = \frac{|D_1|}{|D|} = \frac{371681769.2}{3949336} = 94.11$$

$$b_1 = \frac{|D_2|}{|D|} = \frac{-2417924.4}{3949336} = -0.61$$

$$b_2 = \frac{|D_3|}{|D|} = \frac{2492060.95}{3949336} = 0.63$$

From $y = a + b_1 x_1 + b_2 x_2$ (4)

Substituting for the computed values of a, x_1 and x_2 in the above regression equation gives $\mathbf{Y = 94.11 - 0.61x_1 + 0.63\ x_2 + e}$ being the model developed from the result or the noise survey carried out (study).

However, validation test were computed for all the results when 1, 2 or 8 machines are operating and the validation result is shown in Table 4.13

The model validation result (Appendix B and D) as displayed in table 4.13 is based on the model developed from the result of the studies.

Table 4.13: Validation Test Result

X_1	X_2	Y
0.5	1	94.4
5	1	91.69
10	1	88.64
15	1	85.59
20	1	82.54
25	1	79.49
0.5	2	95.07
5	2	92.31
10	2	89.30
15	2	86.22
20	2	83.17
25	2	80.12
0.5	8	98.85
5	8	96.10
10	8	93.05
15	8	90.00
20	8	86.95
25	8	83.90

Note:

X_1 = Distance

X_2 = No of machines operating

Y = Noise level

Table 4.14: Data used in Determining the Accuracy of the Model

Y_c	Y_m	$(Y_m - \bar{Y})^2$	$(Y_c - \bar{Y})^2$
94.4	92.90	17.472	32.262
91.69	91.00	5.198	8.821
88.64	87.40	1.742	0.006
85.59	85.80	8.526	9.797
82.54	81.50	52.128	38.192
79.49	78.00	114.918	88.193
95.07	95.40	44.622	40.323
92.31	92.60	15.054	12.888
89.30	90.10	1.904	0.336
86.22	88.20	0.270	6.250
83.17	85.60	9.734	30.803
80.12	80.70	64.320	73.960
98.85	98.90	103.632	102.617
96.10	97.10	70.224	54.464
93.05	93.10	19.184	18.749
90.00	89.40	0.462	1.638
86.95	86.30	5.856	3.133
83.90	83.00	32.718	23.232
$\sum$ **1597.39**	**1597.00**	**567.964**	**542.664**

Table 4.15: Noise Level for Kure Market Mill A MC1

Pt	N(dB)	S(dB)	W(dB)
Ear level	93.90		
7m	88.20	90.00	89.80
14m	86.80	87.90	88.50
21m	79.50	81.40	83.10
28m	73.10	71.70	74.70
35m	71.00	69.90	72.30

Table 4.16: Noise Level for Kure Market Mill B MC 1

Pt	N(dB)	S(dB)
Ear level	93.70	
7m	89.50	88.90
14m	84.90	84.70
21m	82.10	81.80
28m	77.10	75.50
35m	70.60	72.10

Table 4.17: Noise Level for Kure Market Mill C MC1

Pt	N(dB)	S(dB)
Ear level	92.9	
7m	89.70	90.10
14m	86.90	88.00
21m	79.70	81.70
28m	74.90	79.00
35m	71.30	73.40

Table 4.18 Noise Level for Kure Market Mill D MC1

Pt	N(dB)	S(dB)	W(dB)
Ear level	94.80		
7m	89.20	88.40	89.00
14m	84.20	84.40	84.80
21m	82.30	81.70	81.20
28m	76.10	75.00	75.30
35m	72.60	73.10	72.90

Table 4.19 Noise Level for Kure Market, Mill A Machine 1 and 2 Operating

Pt	N(dB)	S(dB)	W(dB)
Ear level	95.2		
7m	93.40	92.90	93.80
14m	88.10	88.90	89.30
21m	84.50	83.30	85.70
28m	78.40	78.70	78.00
35m	77.9	76.10	74.70

Table 4.20 Noise Level for Kure Market, Mill B, Machines 1 and 2 Operating.

Pt	N(dB)	S(dB)
Ear level	96.00	
7m	93.30	93.50
14m	90.90	89.30
21m	84.90	84.40
28m	78.70	77.10
35m	76.20	75.50

Table 4.21 Noise Level for Kure Market, Mill C Machine 1 and 2 Operating.

Pt	N(dB)	S(dB)
Ear level	95.80	
7m	92.60	92.90
14m	89.40	89.00
21m	85.70	84.40
28m	78.10	77.00
35m	76.90	74.50

Table 4.22 Noise Level for Kure Market, Mill D Machine 1 and 2 Operating.

Pt	N(dB)	S(dB)	W(dB)
Ear level	95.7		
7m	91.60	92.40	92.80
14m	89.70	89.40	89.40
21m	86.70	86.00	87.90
28m	79.70	79.90	78.90
35m	73.90	77.50	74.30

Table 4.23: Noise Level for Kure Market for Mills A-D with Two Machines Operating Each

Pt	N(dB)	S(dB)	E(dB)	W(dB)
Ear level	98.70	97.70	98.40	98.00
7m	96.50	96.00	96.20	96.90
14m	92.10	91.20	92.77	91.80
21m	87.70	87.50	87.40	88.90
28m	83.00	83.90	83.70	84.00
35m	77.20	77.40	79.00	78.30

Table 4.24 Average Noise Level of Kure Market in all Direction in Mills A-D.

Point	A	B	C	D	Average reading
Ear level	93.50	93.10	93.00	92.80	93.10
7m	89.33	89.20	89.90	88.87	89.32
14m	87.73	84.80	87.45	84.47	86.11
21m	81.33	81.95	80.70	81.73	81.43
28m	73.17	76.40	76.95	7547	75.50
35m	72.67	75.35	75.85	74.00	74.47
Ear level	95.20	96.00	95.80	95.70	95.68
7m	93.37	93.40	92.75	92.27	92.95
14m	88.43	90.10	89.20	89.50	89.31
21m	84.50	84.65	85.05	86.63	85.21
28m	78.36	77.90	77.55	79.50	78.33
35m	76.23	75.85	75.70	75.20	75.75
Ear level	98.70	97.70	98.40	98.00	98.20
7m	96.50	96.00	96.20	96.90	96.40
14m	92.10	91.00	92.77	91.80	91.92
21m	86.70	87.00	87.40	86.90	87.87
28m	83.00	83.90	83.70	84.00	83.65
35m	76.60	77.00	77.60	76.70	76.98

Table 4.25 New Kure Market Data used to determine the Accuracy of the Developed Model.

Yc_k	Ym_k	$(Ym_k - \bar{Y}_k)^2$	$(Yc_k - \bar{Y}_k)^2$
94.440	93.825	66.016	76.388
90.470	89.320	13.104	22.753
86.200	86.110	0.168	0.250
81.930	81.430	18.233	14.213
77.660	75.500	104.040	64.642
73.390	74.470	126.113	151.536
95.070	95.680	99.600	87.797
91.100	92.950	52.563	29.160
86.830	89.310	3.610	1.130
82.560	85.210	0.240	9.860
78.290	78.328	54.346	54.908
74.020	75.753	98.943	136.422
98.850	98.200	156.250	172.923
94.880	96.400	114.490	84.272
90.610	91.920	38.688	24.108
86.340	87.875	4.731	0.4096
82.070	83.650	4.203	13.177
77.800	76.975	76.126	62.41
$\sum$ 1542.51	1552.456	1031.464	1006.359

$\bar{Y}_k$ =Mean of the new Kure market computed noise level

Y_{ck} = computed Noise level of Kure market

Y_{mk} =measured Noise level of Kure market

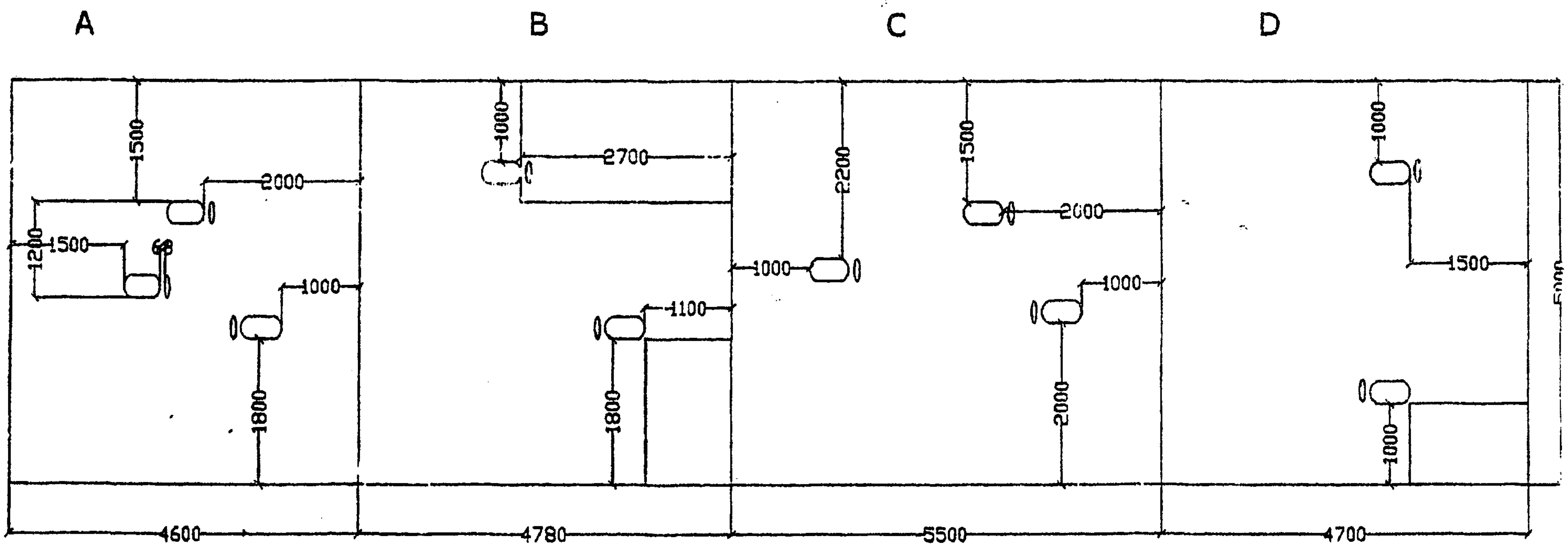
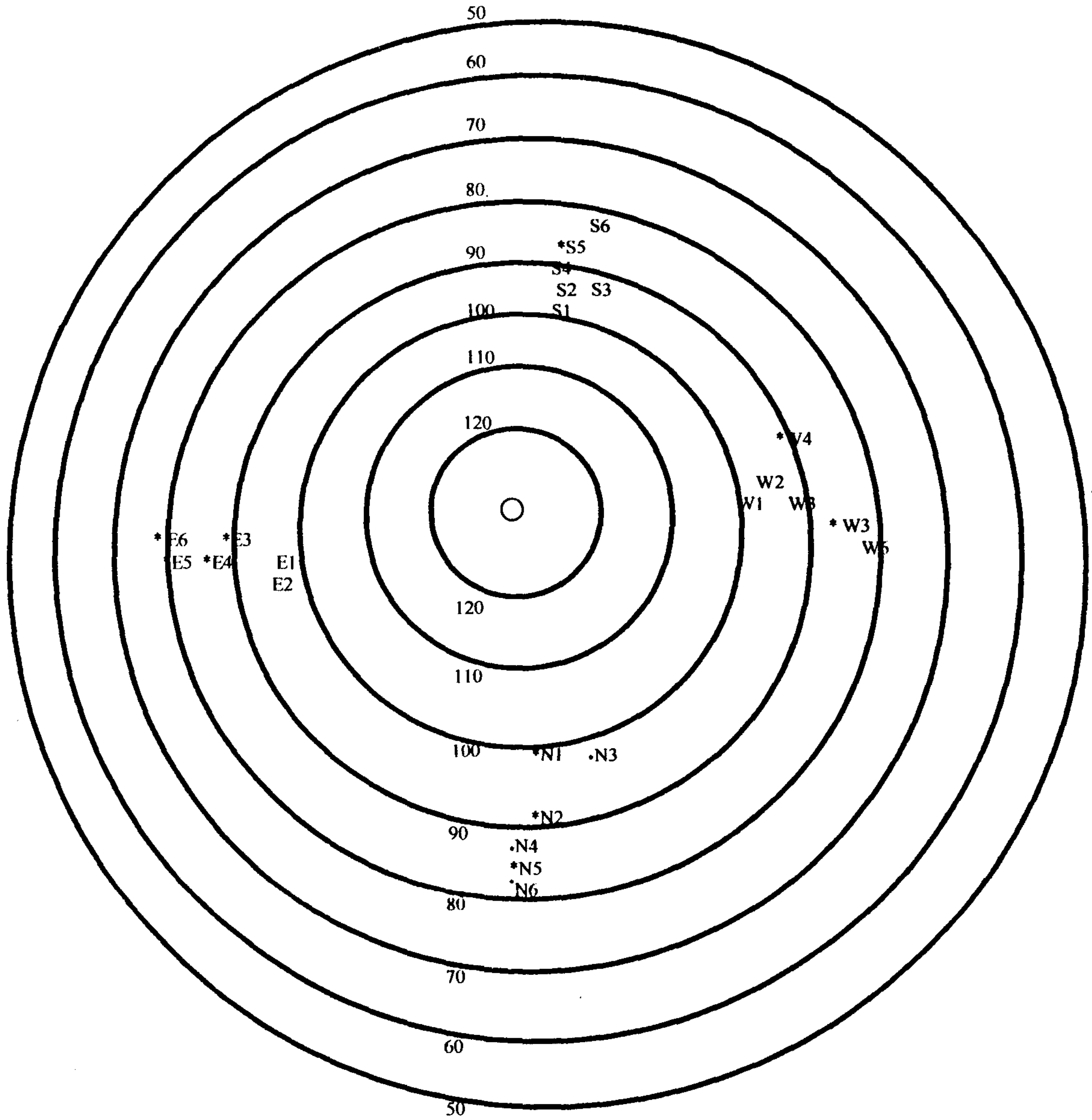


fig.4.1: Layout for machine and operators locations in each mill

KEY	
0	OPERATOR
⬭	MACHINE POSITION
SCALE:	1 : 100
A,B, C, D	Stands for shops A - D
ALL DIMENSION IN MM	



Key
N = North direction
W = West "
E = East "
S = South "

Fig.4.2. Range showing points of noise level concentration of mills ABCD in the four directions.

CHAPTER FIVE

5.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

5.1.1 The Mills

There is one single structure housing the mills which was partitioned into four different shops each having two or three machines in it, and about four (4) operators work in each shop. The dimension in each shop and the location of the machines differ. Yisa (2005) observed that structures housing the mills were erected not on the basis of any standard, but on the basis of availability of land within the area of interest; the installation of machines was based purely on the owner's preference. Doors and windows were of different sizes and hence do not follow any architectural standards.

Dimensions of the entire building and each single shop were taken. The shops housing the mills are of different sizes depending on the number of machines in them. In shops A and C, there are three machines each, while shops B and D have two machines each. Two types of machines are common to all shops. These are the Hammer and Plate mills. The dimensions of the mills are as presented in table 4.1.

The dimension as seen in table 4.1 are not of any standard and therefore ergonomics consideration in the design, construction and the installation of these machines were ignored, hence the operators either stand erect during operation or they use a small stool to perform the operation. These is no standardization for the workspace geometry as each shop space provided depends on the number of machines in each shop and hence no consideration for standardization for both space occupied by the machines, the space between one machines and another and the workspace is neglected.

The temperature within each shop (35-36^{0}C) is not conducive for operators in all the days we visited the market, as the shops are too hot during the hours of 12:00noon to 4:30pm and the ventilation provided is very poor, as the windows are too small to provide the ventilation required during operation. Therefore, during operation, the stuffy environment coupled with the dust from the ground materials makes the mill uncomfortable, and the operators are exposed to heat, dust and excessive noise.

Yisa and Yusuf (2006) found out that the noise levels in the mills when all the machines are working at operator's ear level exceed 95dbA which is clearly far above the level set as safe by all international organizations.

5.1.2 Analysis of Measured Result

Before the commencement of the measurement, the noise level of the area when all the machines were not in operation (off) were determined and it varies between 41 and 50dB, because this is a market area coupled with background noise. Each time the machines are operating, the noise is so high that traders around the market grumble about the excessive noise coming from the mills, as the noise disturb their trading and communication and hence it evoke unnecessary frustration and anger among the traders and buyers.

From the measurements recorded, the following results as presented in Tables 4.2 to 4.10 were obtained. Table 4.2 to 4.5 show the noise levels of mills A – D when only one machine was operating in only one shop. Table 4.6 to Table 4.9 displays the noise levels of mills A –D when two machines were operating in one shop and the remaining machines in the other shops were switched off, and Table 4.10 shows the noise reading when two machines were on in all the four mills. Table 4.2 shows the noise levels of mill A when only one machine was operating as 72 dB as the minimum level about 25 meters away from the mill in north direction, and 92.9 dB was recorded as the maximum noise level at operators ear level in the same north direction. Table 4.3 shows the noise level of mill B after that of mill A was shut off. A noise level of 80.3dB was recorded as the minimum and a maximum of 92.8 dB was also recorded. Table 4.4 shows the noise levels of mill C recorded when only one machine was on. A minimum of 74.6dB at about 25metres away from the source and a maximum of 92.7dB, 5metres away from the mill in the same north direction were recorded. Table 4.5 shows the noise levels of mill D when only one machine was on. The reading shows a minimum noise level of 71.5 dB, 25 metres away in the east direction and a maximum of 93.1 dB in north direction, at operator's ear level. After the noise level of one machine in operation was recorded in each of the four mills , the researcher solicited the co-operation of the owners to kindly put two machines in operation in each shop one after the other, so that the noise levels in each shop can be recorded separately, and they co-operated. Tables 4.6 to 4.9 show result of the noise levels of two machines in operation recorded separately one after the other. Noise levels were taken at operators ear level and then at an interval of 5meters,10 meters, 15meters, 20meters and 25 meters away respectively as seen in the tables.

In Table 4.6, two machines in mill A were in operation at the same time and the noise levels recorded was 95.9 dB at operator's ear level, which was the highest noise level while the lowest in the southern direction was 78.7 dB.

Table 4.7 depicts noise level of two machines in operation in mill B, and the level at operators ears was 95.1 dB and the highest level recorded was at the operators ear level, and a minimum noise level of 76.3 dB was recorded in the northern direction about 25m away from the noise source.

Table 4.8 shows the noise level of two machines in mill C, and noise level of 95.5 dB at operator's ear level was recorded and a minimum noise level of 81.1 dB was obtained.

Table 4.9 shows the noise levels of two machines working at the same time in Mill D. A 94.3 dB noise level at operator's ear level which is also the highest recorded and a minimum of 79.0 dB was observed.

After noise levels were recorded for one machine in operation in each shop, and two machines in operation also in each shop, the researcher's requested the owners to switched on two machines in all the shops and noise levels were recorded as done earlier on. Table 4.10 shows noise level for the combine mills ABCD. The minimum level is 81.7dB, 25 metres away and 99.9 dB at operators ear level in the western direction.

Noise at operator's ear level exceeds 97 dB in each of the shops. However, most of these readings carried out outside the mill building are influenced by background noise, because of noise propagation. Some of the readings were influenced by wind movement and background noise.

Figures 4.3 to 4.6 (Appendix c) shows the noise levels of mills A, B, C, and D respectively taken in the specific direction shown, displayed individually at different directions when only one machine was in operation. Figures 4.7 to 4.10 depicts the noise levels of mills A, B, C and D respectively at the specific direction the measurement was taken when two machines are operating separately in each shop. Figure4.11 shows the noise level of all the mills when all the machines (8) are operating. These clearly indicate that operators and traders are constantly exposed to excessive noise above the allowable limit.

From the noise levels obtained, a model was developed using the average readings in all the mills when 1, 2 or all the machines are operating in the mills as appeared in Table 4.11. Using this reading the model can be verified for accuracy and we can use the model to predict the noise level of a certain distance if the numbers of machines operating are known.

The following were considered for this model,

Let y = Noise level

X_1 = Distance

X_2 = Number of machines

The average readings or values of all the noise levels recorded were computed which facilitate the depicting of the model.

5.1.3 Model Validation Test

A validation test carried out as seen in Table 4.13 using multiple regression model to determine the accuracy of the developed model and the measured values. Note: Multiple regression model considered with three variables (y_1, x_1 and x_2) is given by equation (4).

5.1.4 Model Accuracy Test

The model accuracy check was carried out to find out the percentage error of the model and the lesser the error the more accurate the model, and is calculated as follows:

$$\text{Model accuracy test} = \frac{\text{True value} - \text{Computed value}}{\text{True value}} \times 100$$

If we now take one of the values from our reading and one from the validation result we can calculate the model accuracy test as follows

$$\text{Model accuracy test} = \frac{85.80 - 85.59}{85.80} \times 100$$

$= 0.2476\ \%$

The percentage accuracy test for the results used as computed above shows that the model has an error of about 0.2 % and hence very low, therefore the model can be accepted.

5.1.5 Coefficient of Determination

The accuracy of the regression model developed was computed by finding the coefficient of determination (r^2) between the measured values and the computed values of Y, using the following expression as outlined by Lucey (1989).

$$r^2 = \frac{\sum(Y_c - \bar{Y})^2}{\sum(Y_m - \bar{Y})^2}$$

$$r^2 = \frac{542.664}{567.965} = 0.955 = 95.55\%$$

Where:

r^2 = coefficient of determination

Yc = computed noise level using the developed model

Ym = measured noise level from the survey conducted

$\bar{Y}$ = mean of measured noise level

The coefficient of determination between the measured and computed values of Y calculated from Table 4.14 reveals that accuracy of model is as high as 95.55%. In other words the variation between the actual measured noise level and the computed noise level using the developed model does not exceed 4.45%. As such the model is adequate enough for use in predicting noise level at a given distance from a source.

From the results obtained and the model developed it is clearly shown that the adverse effect of agricultural noise in Gwadabe market on the mill operators is alarming, as it exceeds the allowable noise level of 85dB. It is clearly established that even at 20 meters and 25 meters away from the mills when all machines are in operation, the noise level is around 81.7 to 88.1dB which is enough to cause discomfort and annoyance, and hence the traders around the market are liable to experience hearing abnormalities which can lead to either temporary or permanent threshold shift. These contravene the maximum allowable exposure of 85 dB for a maximum of eight (8) hours as observed by many scholars and international regulatory organizations. Blake and Mitchell (1972), NIOSH (1999), Washington (2004) in their studies stated that the ear function without risk of having a permanent damage when the noise level it is exposed to is below 85dB and hence agree that noise exposure above 85dB for more than 40 hours per week can lead to loss in hearing .Therefore operators at Gwadabe market are in a serious danger of loss of hearing due to the number of hours worked daily and the degree of exposure. Other scholars like Smith *et al.*,(1994) and Yisa (2005) all reported that exposure to noise levels greater than 85dB for eight (8) hours daily seriously damages health. The United State Environmental Protection Agency (1976) specifies a maximum outdoor level of 60 to 65dB.

This clearly shows that the operators, owners and other market stakeholders are prone to developing a permanent hearing problem because they are constantly exposed to noise above the allowable limit for more than ten (10) hours daily. This study established that even at 25metres away from the mills when all machines are in operation, the noise level is between 81.7 to 99.9dB.

Studies by *Cohen et al.,* (1970) compared the mean hearing levels of workers and those of a controlled group for several intensities and several durations of exposure and found out that noise levels between 85 and 88dB could be harmful to ear, and even at 75dB there was some loss of hearing.

Also from the model developed it can be seen that even at 50 meters away from the source of the noise, the noise reading is 69.33dB which is enough to create enormous discomfort to traders and surrounding residents. This can affect people's hearing and have serious health implications if measures are not taken to reduce the exposure level. Moreover, scholars like Roth (1970) and Martin (1975) revealed definite risk of hearing damage associated with prolonged exposure to noise levels between 85 and 90 dB. Studies by Prasanna Kumar *et.al.,*(2008) and Prasanna Kumar *et.al.,*(2008b) in Indian Oil Mills and Indian rice Mills reported that the noise coming from these mills all exceed 90dB, and hence in line with the findings of these study.

The model developed can be used to calculate the area where noise is at minimal and will not pose any health threat to the traders and hence a safer place for the traders to conduct their activities.

To confirm the accuracy of the model, another noise survey was conducted in the new Kure market, which is located just behind the Kure central market in Minna metropolis also in Niger State. The coefficient of determination (r^2) of the Kure market noise level is computed using the measured (Y_{mk}) and computed (Y_{ck}) values using Lucy (1989) expression

$$r^2 = \frac{\sum\left(Y_{ck} - \bar{Y}\right)^2}{\sum\left(Y_{mk} - \bar{Y}\right)^2}$$

$$r^2 = \frac{1006.359}{1031.464}$$

$r^2 = 9.76 = 97.57\%$

This confirm the accuracy of the predictive model because comparison was made between the measured and computed noise levels of the two markets to test the accuracy of the model and was found adequate, because the noise level of Kure market between the measured and the computed values is as high as 9 and can therefore be use to predict noise levels from any given source. The computed Noise levels was obtained using the model developed and then applying the new kure market measured Noise level to get the computed Noise level of the Kure market, hence this accuracy. From the noise levels of the Kure central market,it is still clear that operators are exposed to excessive noise always of above 98dB and even at 35 metres away from the mills, the noise level is still above 77dB when all the machines are operating hence the susceptibility is the same.

5.1.6 Analysis of response to questionnaire

The nature of work in the mills is too demanding as operators normally work for 10 – 12 hours daily depending on the availability of work. This means that the operators will be expose to excessive noise for the period of the operation, and if there's work they will continue to work for at least 10 hours, which exceed the maximum allowable hours for excessive noise exposure. Most of the operators have been on the job for between 3–5 years. This shows that the operators have been on the job at least three years and for the period they have been working they are subjected to noise well over 85dB. On the issue of closing for break during operation, about 12 operators representing 75% of the sample population said they hardly go for break. It all depends on the availability of work, therefore they normally order for food while working. They confirmed to us that they sometimes eat while working, and the only break time they enjoy is when there is no work. The operators were also asked about their health and if they experienced any side effect as a result of noise exposure. All the operators (16) representing 100% admitted that they do experienced some pains ranging from headache to backache and fever. They also agreed that people must raise their voice if they want to talk to them.

This response is inline with the studies conducted by Blake and Mitchell (1972) which state that the ear function without risk of damage when the sound level operated is below 85dB to 120dB. The assertion by workers of experiencing some pains ranging from headache, backache to fever conform with the studies carried out by Kryter (1980),who reported some physiological response or symptoms related to noise exposure and these include response of anger, headache, general illness, hypertension and other biological disorders. These findings also is in line with the findings of Sieber *et.al.*,(1992), Brennan *et.al.*,(1992) and that of Rosenberg *et.al.*,(1991), which all confirmed that exposure to excessive noise for a longer period compromise health.

The researcher believed that the noise the operators are exposed to is the principal agent that causes the following:

(1) Low productivity

(2) Annoyance

(3) Loss of concentration while working

This is because studies by Kahnehman (1973) revealed that depending on the complexity of task, noise may either improve or interfere with performance. His study added that repetitive or mechanical task are greatly affected, while monotonous task illicit beneficial arousal levels and therefore may favourably affect performance. Miller (1974) also revealed that noise is more likely to reduce overall accuracy rather than the total quality of work, and is more likely to affect the completion of complex tasks than the completion of simple task.

This is true, as the operators themselves confessed that they normally experienced weakness of the body and they are easily provoked. They also experience temporary deafness during operation for sometime as long as 5 minutes and after that hearing resumes. The operators normally work from 7am to 6pm every day. They also complained of experiencing backache, headache and pains and they normally go on self medication. Also some of the operators agreed that after closing work at home, they normally increased the volume of their television sets while watching, above the normal volume normally set by their families. Even the traders that are around the mills confessed that most times after leaving the mill area they still feel as if they are within the area and they have to raise their voices when they are talking to people. This negative diminishing effect in hearing is in conformity with studies by Miller (1974), who reported that early effect of noise exposure on the hearing sense organ can first be evidenced by slightly decreased hearing sensitivity.

The study identified areas of high noise exposure and where there are noise hazards. The study clearly confirmed that all these illnesses experienced by the operators and mill owners are directly associated to the extreme daily exposure.

5.2 Conclusion:

The study confirmed that worker's at the mills face danger of exposure to excessive noise,although the health implication may be long term and can be attributed to other factors, it is now evident that, the problems caused by excessive noise exposure supercede its earlier predictions. Operators of agricultural machineries have constantly suffered great stress especially after retirement or at the close of day's work, which culminate to some serious illnesses at old age.

From the study, it was discovered that mill operators and traders in Gwadabe market are exposed to noise level above the maximum allowable limit of 85dB for more than ten (10) hours daily. From different literatures, the exposure is too high and the negative health implication associated with this type of exposure mostly resulted to complete or incomplete seizures in hearing, and can lead to permanent deafness.

The rate at which agricultural workers are exposed to this danger is always on the increasing side, because apart from the fact that the owners are not willing to provide the operators with any protective devices, as this will surge the cost of operations, the majority of operators are untrained and therefore they are not even interested in any protective devices, because majority of them are illiterates and therefore they do not attach any importance to health and safety during operations. The hours worked and the amount of exposure exceed the hours recommended for daily work in a noisy environment, and the level of exposure is above the recommended noise exposure, and these hours worked daily plus the level of exposure makes their health worst and they most of the times resort to self – medication.

Based on the model developed it can be seen that the level of noise the operators and the traders are exposed to is enough to lead to serious health implications and even at far distance away from the source ,the noise level is still high and this is as a result of the noise propagation and background noise.

It has also been established from the responses of the operators with respect to the question asked whether they have started experiencing any health problems. These they answered 'Yes' and almost all of them confessed that they have already started experiencing some health problems, ranging from headache, general body pains, nausea and temporary seizure, in hearing and those seizure sometimes last to up to 5 minutes. These they said, after operation and shutting down the machine, they tend to still feel as if the machine is on, and even after coming out of the shop, they don't normally hear conversation until after sometimes, when their hearing resume. These have been outlined by many scholars as the first steps towards the process of permanent loss in hearing. Therefore, there is urgent need to halt this menace to save the operators hearing.

The entire dimension of the mills and the location of machines in each mill are done to owners preference not based on any architectural or approved design, as such the workspace in the mill does not guarantee safety of operations. This negligence on the part of owners exposes the operators to further risks of belt trapping and other hazards associated with the operation due to the absence of protective guards for the drivers and lack of sufficient working tools.

5.3 Recommendations

Based on the study carried out, the following recommendations are made:

i. Machines for this type of operation should be designed to have a maximum noise levels below 85dB at all times. This is imperative because noise levels above 85dB seriously damaged health and affect human hearing capable of causing hearing loss.

ii. Machines already manufactured and in operation should be equipped with facilities that will reduce the level of noise produced.

iii. Effective lubrication and maintenance should be enhanced to reduce noise associated with wear and tear.

iv. Operators should be equipped with proper protective devices and encouraged to use them at all times during operation.

v. There is need to educate mill operators on the dangers of excessive noise exposure and long hours working in a noisy environment

vi. Government should come out with clear environmental noise regulations guidelines for manufacturers and compel manufacturers to adhere to these regulations.

vii. A noise cancellation speaker may also be located within the sound source to be attenuated, and the cancellation speaker must have the same audio power level as the source of the unwanted noise.

viii. The model could be used to calculate noise levels from a given source.

ix. Government should come out with noise laws, edicts and ordinances that set out specific guidelines for the level of noise allowable in industries residential, and densely populated areas.

x. Machines already manufactured should be equipped with devices that reduces the noise to the allowable level.

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APPENDIX A

QUESTIONNAIRE FOR MILL OPERATORS AT GWADABE MARKET, MINNA

This is a research study to determine the effect of noise propagation on the machine operators. We are soliciting for your cooperation and all information given will be strictly used for Academic purpose only.

Name: ---------------------- Age-------------------------- Sex----------------

Location----------------------------

1. For how long have you been on this job?
2. How many hours do you normally operate per day?
3. How many hours do you normally go for break?
4. During break time, do you normally go outside the mill area to eat?
5. Have you ever experienced any hearing problem?
6. If 5 above in yes. How many times have you been to hospital for treatment?
7. Do you experienced any side effect as a result of noise exposure
8. Do you ever notice that people must raise their voiced to talk to you?
9. Do you realize that you must increase the volume of your radio or T.V to a level too loud for others at home?
10. Do you normally experience annoyance or feel upset during or after operation.
11. How many days do you normally take as leave in a year?
12. During the leave, do you avoid the noisy environment completely?

APPENDIX B

VALIDATION TEST CALCULATION

If we take x_1 as the distance and x_2 as the number of machines operating at a time we can calculate the noise level of each distance using the model developed as follows.

$x_1 = 0.5m$

$x_2 = 1$

- $y = 94.11 - (0.61)(0.5) + 0.63(1)$

  $= 94.11 - 0.305 + 0.63$

  $= 94.4dB$

Let $x_1 = 5m$

$x_2 = 1$

- $y = 94.11 - 0.61(5) + 0.63(1)$

  $= 94.11 - 3.05 + 0.63$

  $y = 91.11dB$

  if $x_1 = 10$

  $x_2 = 1$

  $y = 94.11 - 0.61\ (10) + 0.63(1)$

  $= 94.11 - 6.1 + 0.63$

  $= 88.64dB$

Let $x_1 = 15m$

$x_2 = 1$

- $y = 94.11 - 0.61(15) + 0.63(1)$

  $y = 85.59dB$

  if $x_1 = 20$

  $x_2 = 1$

  $y = 94.11 - 0.61(20) + 0.63(1)$

  $= 94.11 - 12.2 + 0.63$

  $= 82.54dB$

  If $x_1 = 25$

  $x_2 = 1$

  $y = 94.11 - 0.61(25) + 0.63(1)$

  $= 94.11 - 15.25 + 0.63$

  $= 79.49dB$

Let $x_1 = 0.5m$

$x_2 = 2$

- $y=94.11 - 0.61(0.5) + 0.63(2)$

$y=94.11 - 0.305 + 1.26$

$y= 95.07dB$

if $x_1 = 5m$

$x_2 = 2$

$y=94.11 - 0.61(5) + 0.63(2)$

$= 94.11 - 3.05 + 1.26$

$= 92.32dB$

Let If $x_1 = 10m$

$x_2 = 2$

$y=94.11 - 0.61(10) + 0.63(2)$

$=94.11 - 6.1+1.26$

$= 89.27dB$

Let $x_1 = 15m$

$x_2 = 2$

- $y=94.11 - 0.61(15) + 0.63(2)$

$y=94.11 - 9.15 + 1.26$

$y= 86.22dB$

if $x_1 = 20m$

$x_2 = 2$

$y=94.11 - 0.61(20) + 0.63(2)$

$= 94.11 - 12.2 + 1.26$

$= 83.17dB$

Let If $x_1 = 25m$

$x_2 = 2$

$y=94.11 - 0.61(25) + 0.63(2)$

$=94.11 - 15.25+1.26$

$= 80.12dB$

Let $x_1 = 0.5m$

$x_2 = 8$

- $y=94.11 - 0.61(0.5) + 0.63(8)$

$y=94.11 - 0.305 + 5.04$

$y = 98.85dB$

if $x_1 = 5m$

$x_2 = 8$

$y = 94.11 - 0.61(5) + 0.63(8)$

$= 94.11 - 3.05 + 5.04$

$= 96.1dB$

Let If $x_1 = 10m$

$x_2 = 8$

$y = 94.11 - 0.61(10) + 0.63(8)$

$= 94.11 - 6.1 + 5.04$

$= 93.05dB$

If $x_1 = 15m$

$x_2 = 8$

- $y = 94.11 - 0.61(15) + 0.63(8)$

$y = 94.11 - 9.15 + 5.04$

$y = 90dB$

if $x_1 = 20m$

$x_2 = 8$

$y = 94.11 - 0.61(20) + 0.63(8)$

$= 94.11 - 12.2 + 5.04$

$= 86.95dB$

Let If $x_1 = 25m$

$x_2 = 8$

$y = 94.11 - 0.61(25) + 0.63(8)$

$= 94.11 - 15.25 + 5.04$

$= 83.90dB$

Let $x_1 = 50m$

$x_2 = 1$

- $y = 94.11 - 0.61(50) + 0.63(1)$

$y = 94.11 - 30.5 + 0.63$

$y = 64.24dB$

if $x_1 = 50m$

$x_2 = 2$

$y = 94.11 - 0.61(50) + 0.63(2)$

$= 94.11 - 30.5 + 1.26$

$= 65.00dB$

Let If $x_1 = 50m$

$x_2 = 8$

$y = 94.11 - 0.61(50) + 0.63(8)$

$= 94.11 - 30.5 + 5.04$

$= 68.65dB$

APPENDIX C

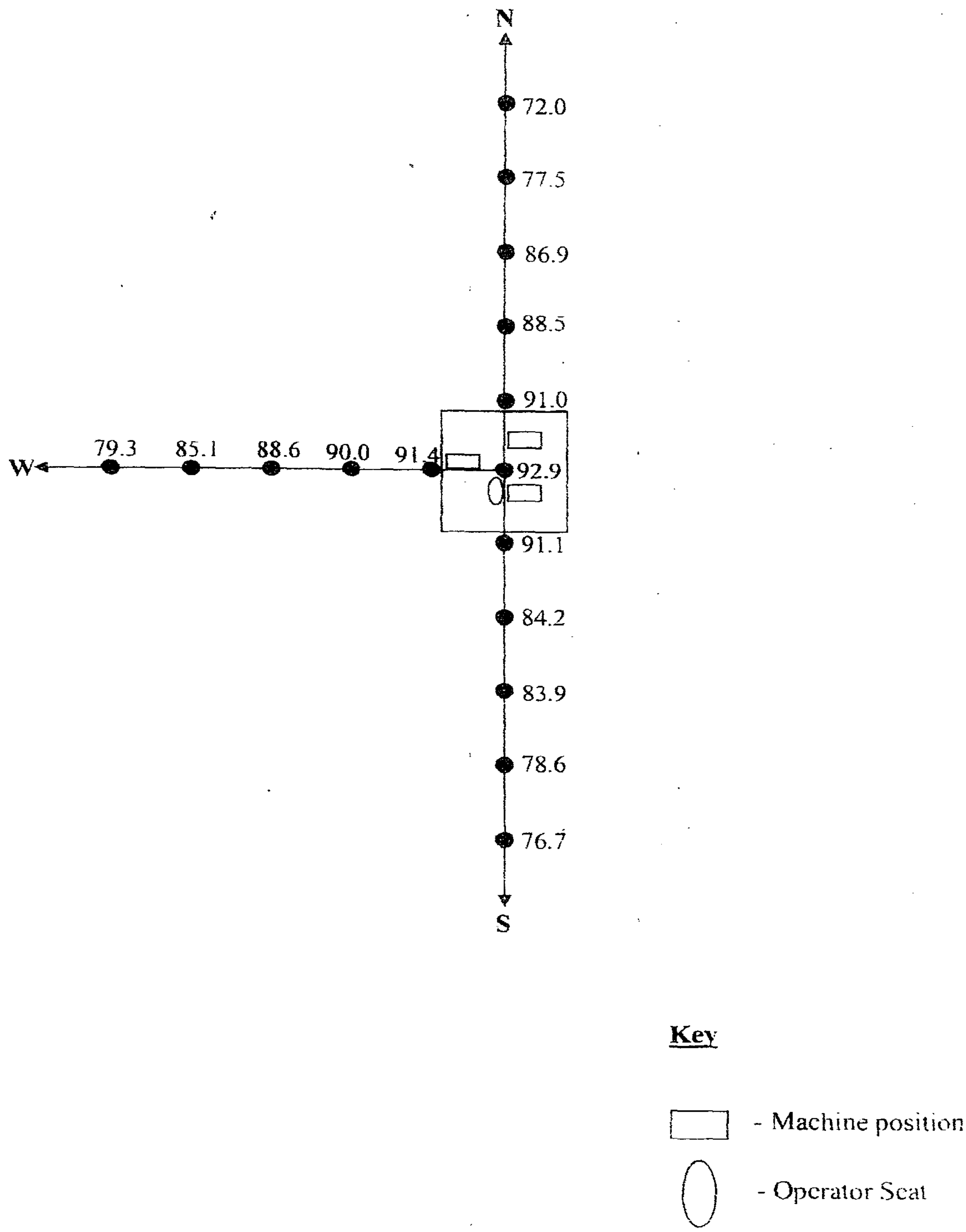


Figure 4.3 Points of Noise Measurement and Noise levels for Mill A

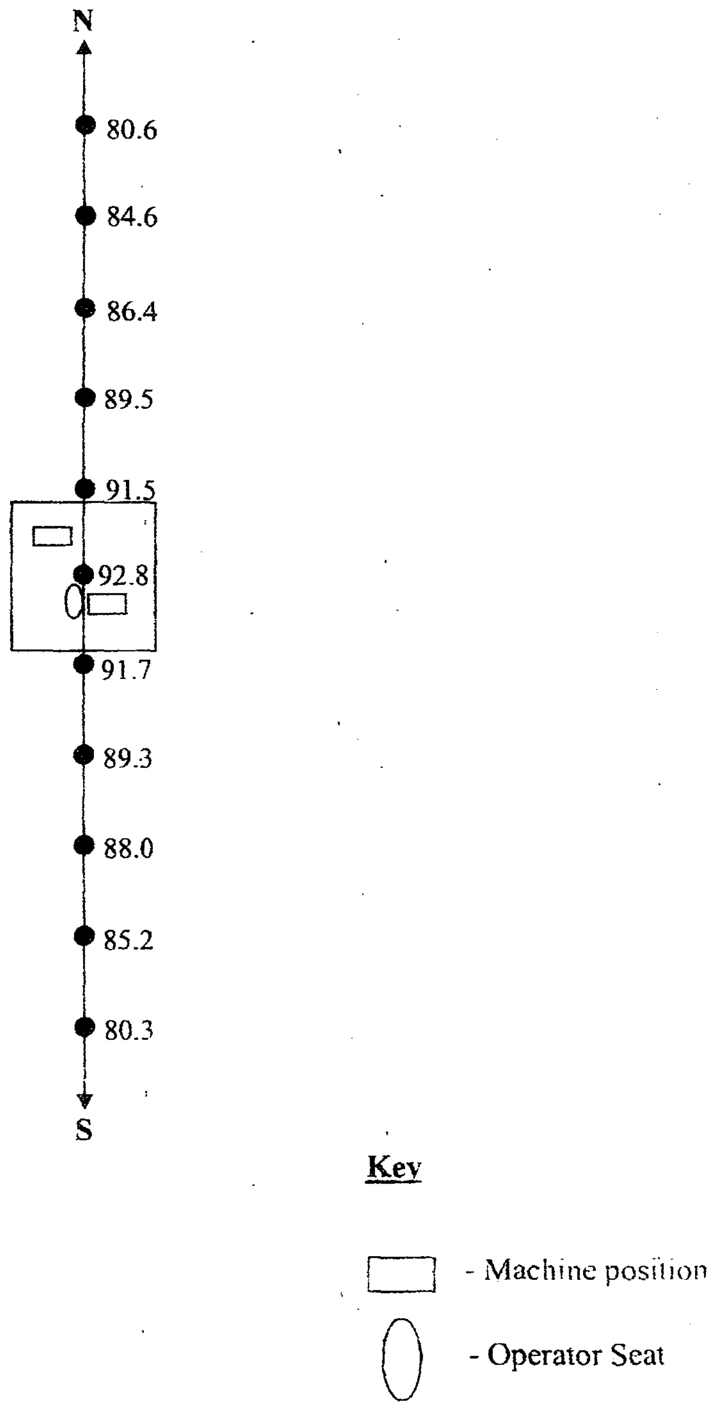


Figure 4.4 Points of Noise Measurement and Noise levels for Mill B

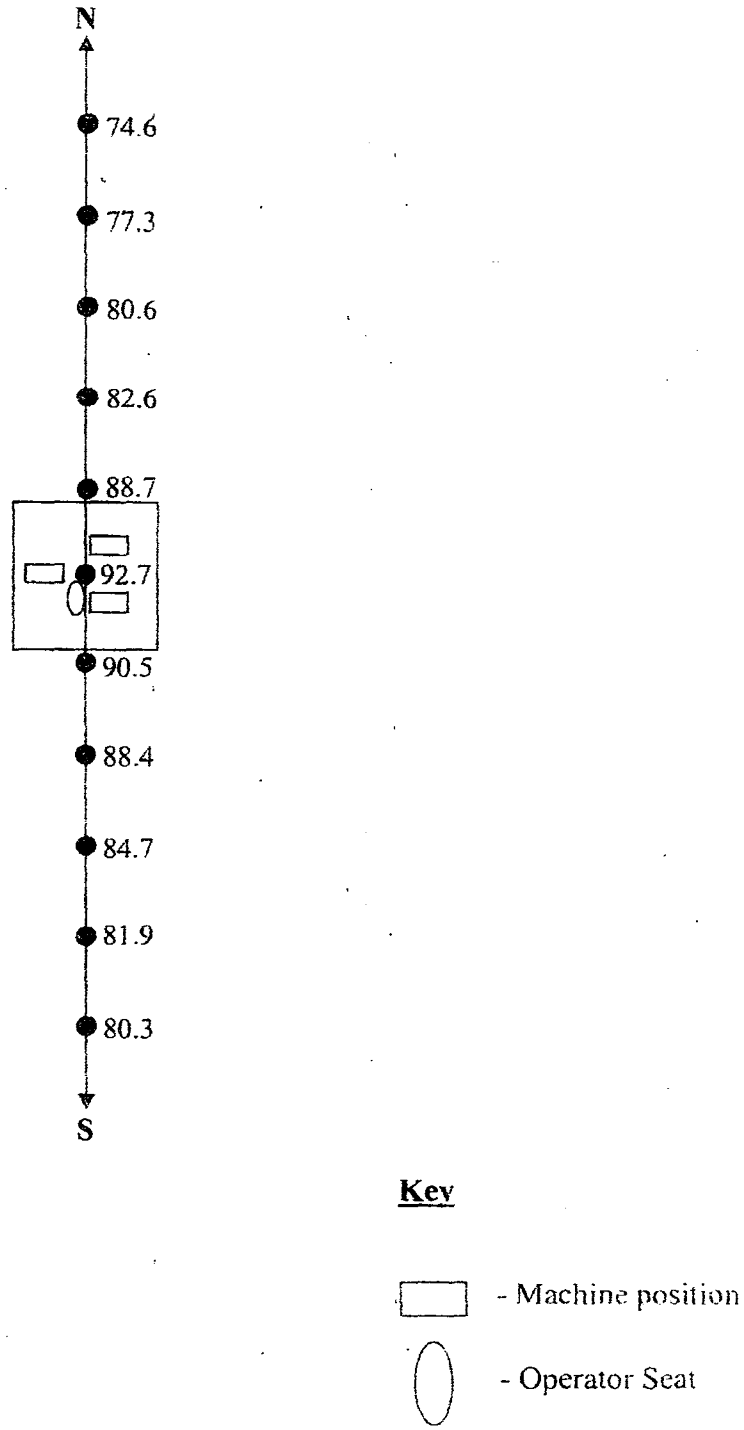


Figure 4.5 Points of Noise Measurement and Noise levels for Mill C

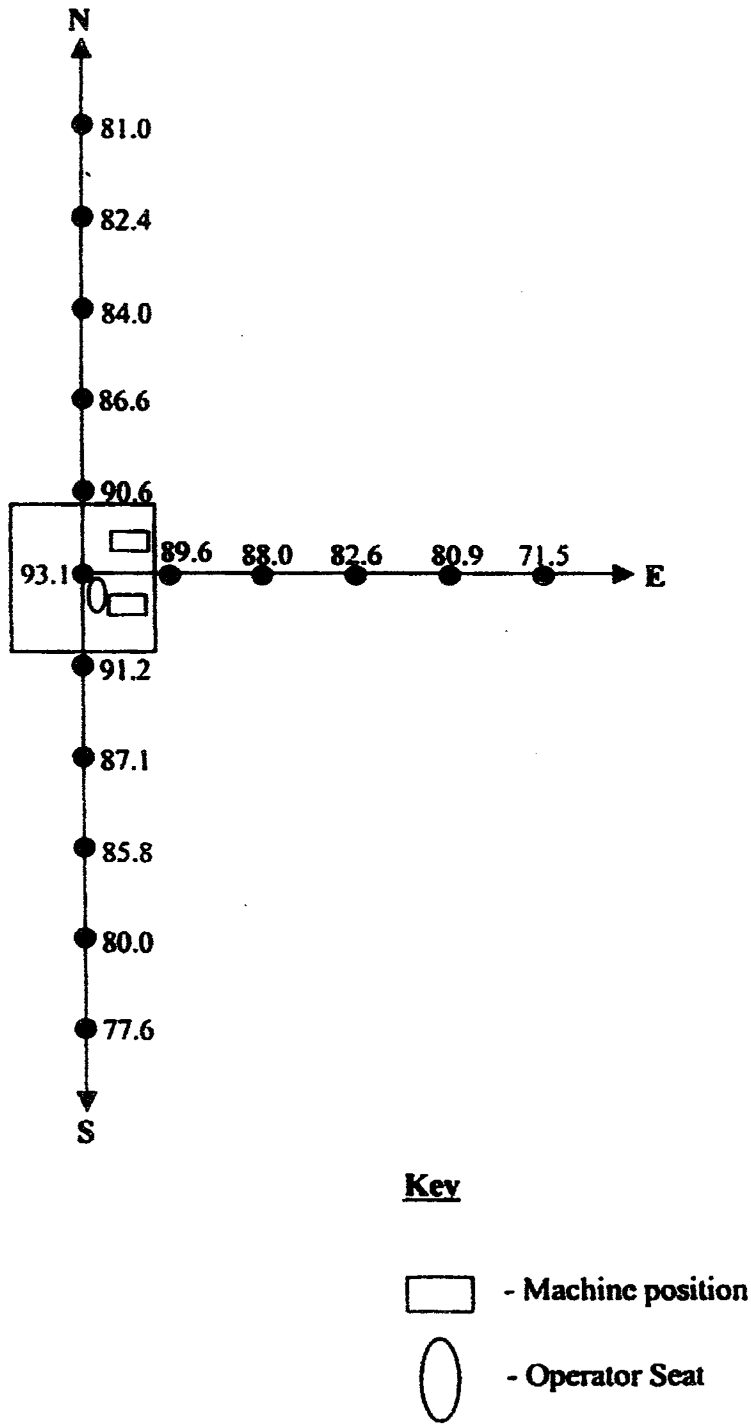


Figure 4.6 Points of noise measurement and noise levels for mill D

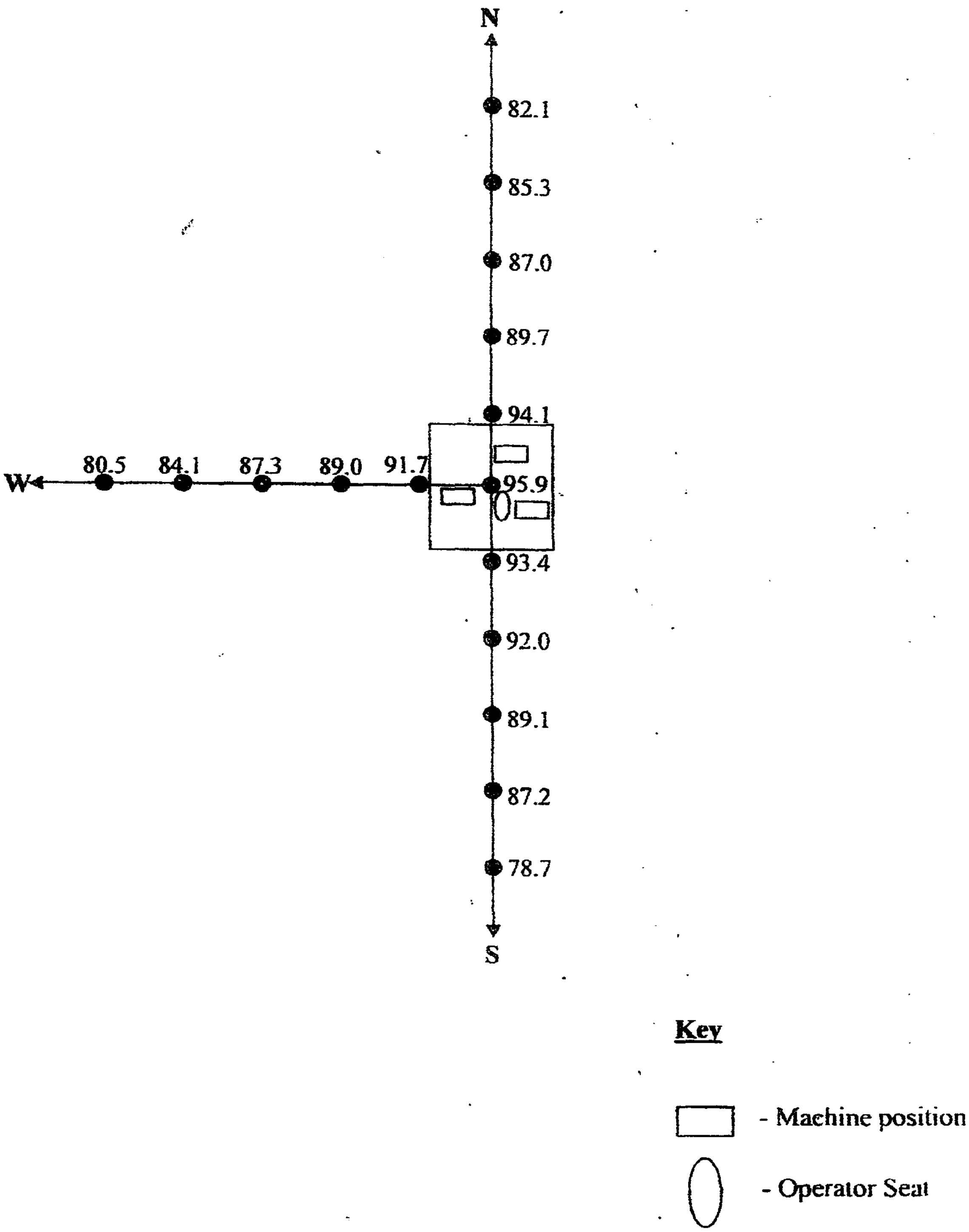


Figure 4.7 Points of Noise Measurement and Noise levels for Mill A Two Machines operating

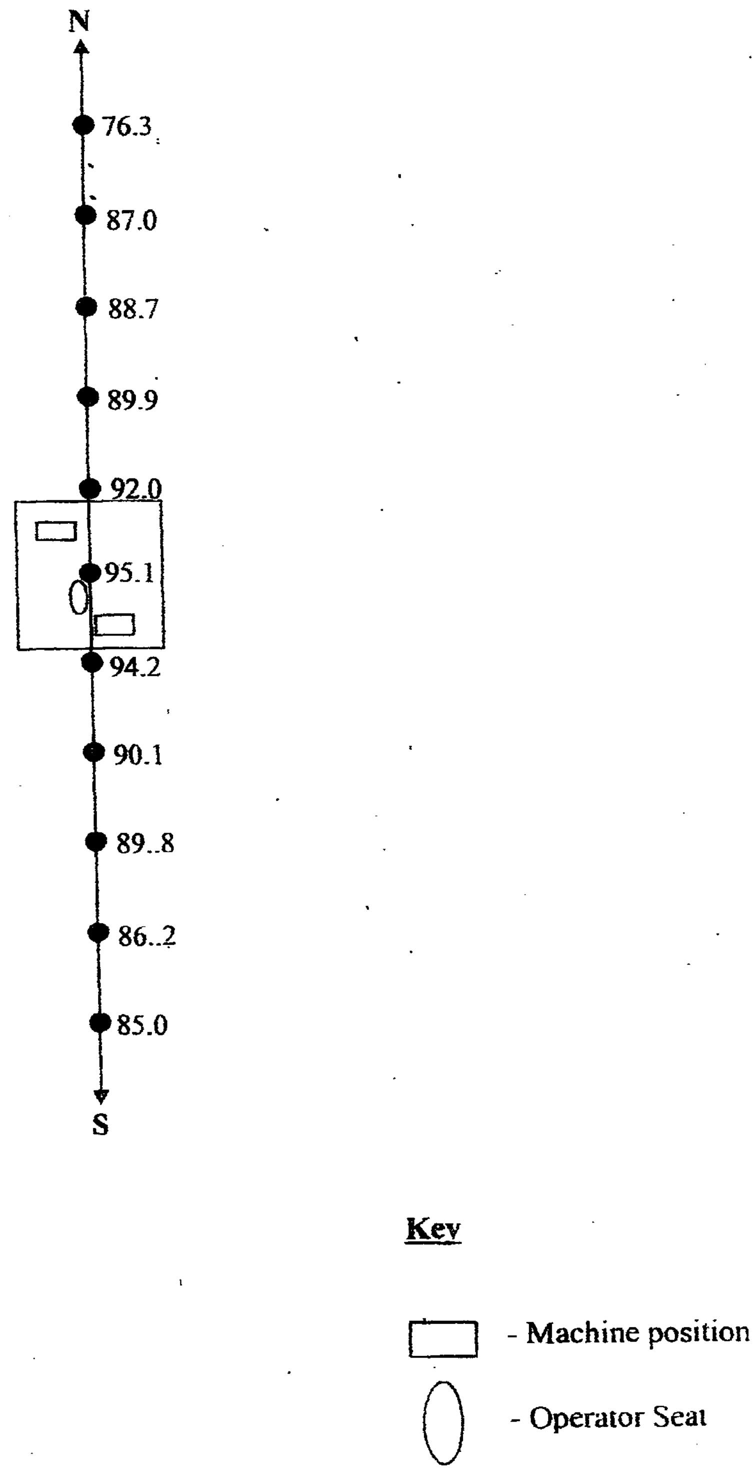
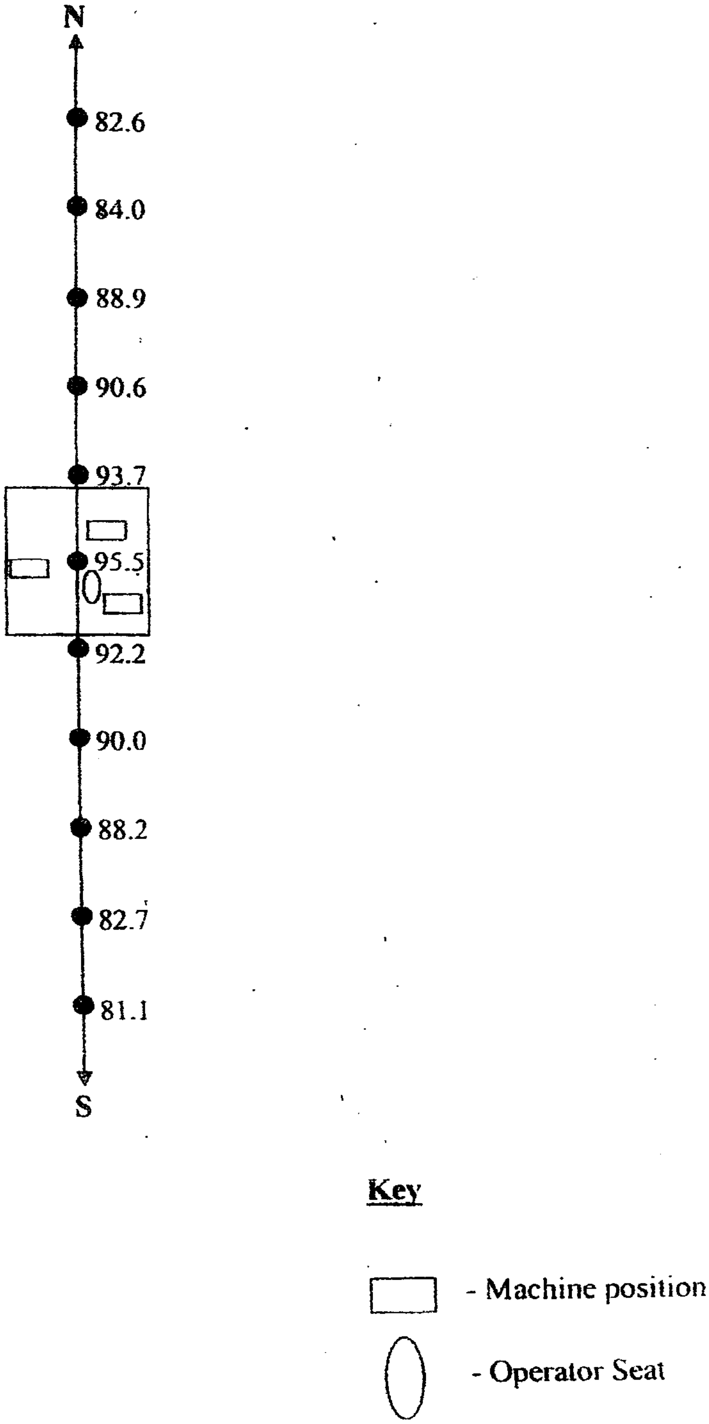


Figure 4.8 Points of Noise Measurement and Noise levels for Mill B Two Machines Operating



4.9 Points of Noise Measurement and Noise levels for Mill C Two Machines Operating

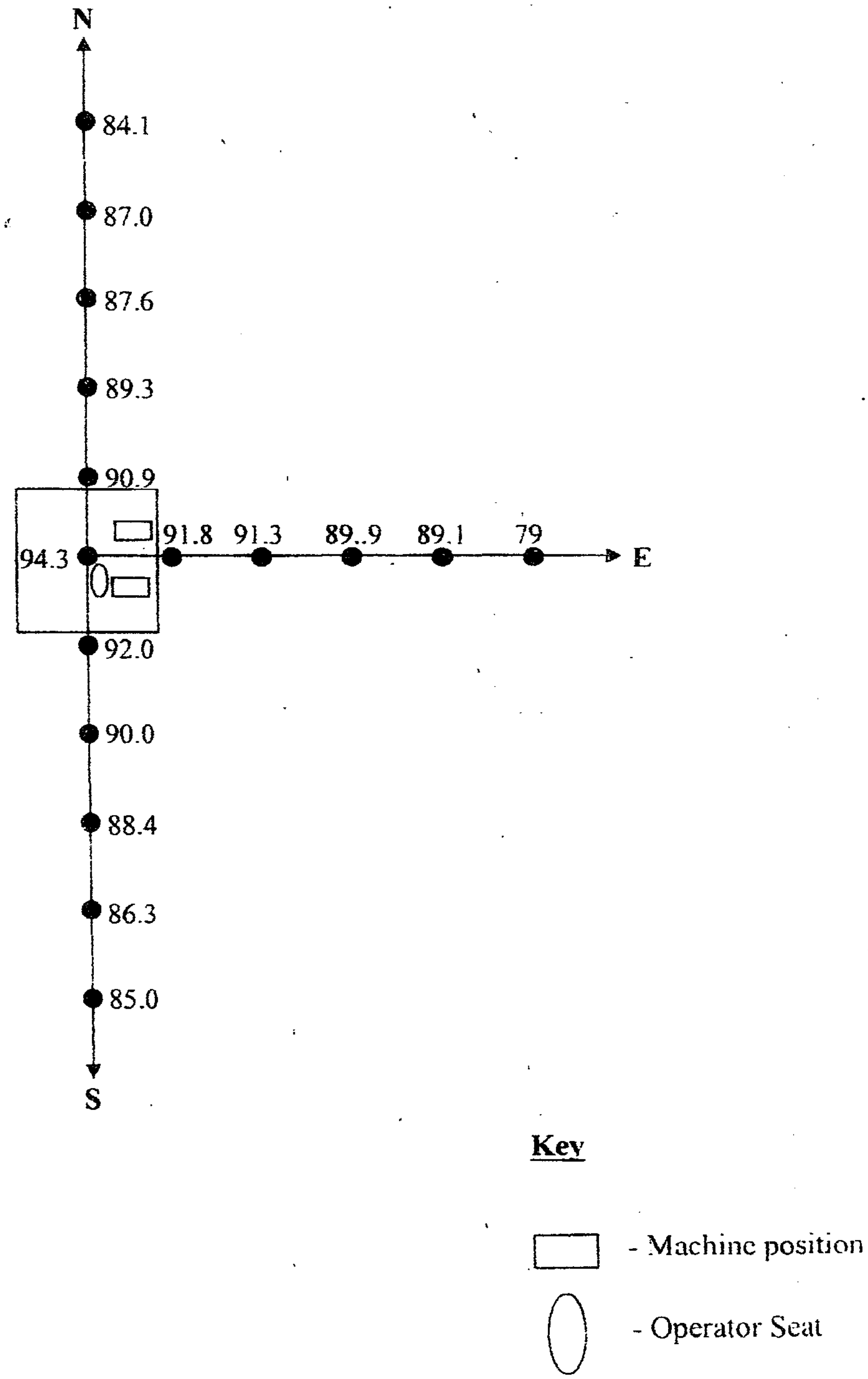


Figure 4.10 Points of Noise Measurements and Noise levels for Mill D Two Machines Operating

APPENDIX D

To compute the validation test of new Kure Central Market reading of the variables (y, x_1 and x_2) using equation (4)

$x_1 = 0.5m$

$x_2 = 1$

$y = 94.11 - (0.61)(0.5) + (0.63(1)$

$=94.11 - 0.305 + 0.63$

$y = 94.44dB$

when $x_1 = 7m$

$x_2 = 1$

$y = 94.11 - (0.61)(7) + 0.63(1)$

$y = 90.47dB$

when $x_1 = 14m$

$x_2 = 1$

$y=94.11 - (0.61)(14) + 0.63(1)$

$y = 86.20dB$

when $x_1 = 21m$

$x_2 = 1$

$y=94.11 - (0.61)(21) + 0.63(1)$

$y = 81.93dB$

when $x_1 = 28m$

$x_2 = 1$

$y=94.11 - (0.61)(28) + 0.63(1)$

$y = 77.66dB$

when $x_1 = 35m$

$x_2 = 1$

$y=94.11 - (0.61)(35) + 0.63(1)$

$y = 73.39dB$

when $x_1 = 0.5m$

$x_2 = 2$

$y=94.11 - (0.61)(0.5) + 0.63(2)$

$y=94.11 - 0.305 + 1.26$

$y = 95.07dB$

when $x_1 = 7m$

$x_2 = 2$

$y = 94.11 - (0.61)(7) + 0.63(2)$

$y = 94.11 - (0.61)(7) + 1.26$

$y = 95.07dB$

when $x_1 = 14m$

$x_2 = 2$

$y = 94.11 - (0.61)(14) + 1.26$

$y = 86.83dB$

when $x_1 = 21m$

$x_2 = 2$

$y = 94.11 - (0.61)(21) + 1.26$

$y = 82.56dB$

when $x_1 = 28m$

$x_2 = 2$

$y = 94.11 - (0.61)(28) + 1.26$

$y = 78.29dB$

when $x_1 = 35m$

$x_2 = 2$

$y = 94.11 - (0.61)(35) + 1.26$

$y = 74.02dB$

when $x_1 = 0.5m$

$x_2 = 8$

$y = 94.11 - (0.61)(0.5) + 0.63(8)$

$y = 94.11 - 0.305 + 5.04$

$y = 98.85dB$

when $x_1 = 7m$

$x_2 = 8$

$y = 94.11 - (0.61)(7) + 5.04$

$y = 94.88dB$

when $x_1 = 14m$

$x_2 = 8$

$y = 94.11 - (0.61)(14) + 5.04$

$y = 90.61dB$

when $x_1 = 21m$

$x_2 = 8$

$y = 94.11 - (0.61)(21) + 5.04$

$y = 86.34dB$

when $x_1 = 28m$

$x_2 = 8$

$y = 94.11 - (0.61)(28) + 5.04$

$y = 82.07dB$

when $x_1 = 35m$

$x_2 = 8$

$y = 94.11 - (0.61)(35) + 5.04$

$y = 77.80dB$